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# EXERCISES IN CHEMISTRY

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BY

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LECTURER IN CHEMICAL LABORATORY

AND

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ASSISTANT PROFESSOR OF INORGANIC CHEMISTRY, IN THE  
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# PART I

## LABORATORY EXERCISES

### SUGGESTIONS FOR THE STUDENT

29 Mar 30 J. W. G. S.  
Your success in the laboratory will depend in a large measure upon your faithfulness in following suggestions and your skill in manipulation. Note carefully the following points:

1. Keep your apparatus and surroundings clean. Failure to do so will result in erroneous conclusions.

2. Study your assignment *before* coming to the laboratory, and lay out a plan of action. Students who do not follow this suggestion are almost certain to drop behind the class.

3. Do not use more material than necessary. Chemicals are expensive and the use of large quantities wastes your time and frequently obscures results.

4. *Work independently of your neighbors.* If you need assistance, secure it from your textbook or from your instructor.

5. Keep all bottles in their proper places and use the utmost care to protect your reagents from contamination. See 2 (c) and (d) in Chapter I.

6. Do not throw anything away until you are sure that you have no further need for it. Throw solids into the waste jars and liquids into the sinks. Acids should be washed out of the pipes with a copious supply of water.

7. Keep an accurate record of all work in a notebook. Observe the following points carefully:

(a) Notes must be recorded *at the time the experiment is performed.* Be brief and concise.

(b) Record what you do, without repeating the directions; a drawing may save a lengthy description of apparatus; tell what you see; give your conclusions from the phenomena observed; answer all questions both direct and implied; if possible write equations for all reactions.

(c) Do not take notes or record data on loose pieces of paper. *Notes taken in this manner will not be accepted*, but may be taken up and destroyed by the instructor.

(d) Keep in mind that it is more important that your notebook should be a faithful history of your daily work than that it should be neat and beautiful; neatness, however, both in the notebook and in experimentation, is a factor in determining your standing.

8. Just before leaving the laboratory at the end of the period, see that gas and water are shut off, all bottles are in place, and that the desk is clean.

Remember that "each chemical experiment is a question put to nature, and forethought and care are necessary in putting the question, and study and reflection in interpreting the answer."

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## ACKNOWLEDGMENT

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## TO THE TEACHER

The thought which has been uppermost in the selection of material for this series of experiments is that the ability to think and reason represents a higher type of education than the training of the memory. Accordingly many questions, both direct and implied, are scattered through the experiments with the double object of training the worker's observation and of teaching the fundamentals of the science.

The number of experiments is sufficiently large to enable the teacher to select those best suited to the needs of his class. Many quantitative experiments are included for the purpose of offering sufficient variety to meet the needs both of beginners and of those who have had some experience in elementary chemistry. The quantitative experiments have been selected with a view to develop skill in manipulation, illustrate fundamental facts and give a comprehensive drill in calculations. If any of these experiments seem too difficult or involve too expensive equipment for a class exercise, it is suggested that some may be performed as a demonstration either by the instructor or by the students who have had an opportunity to try the experiment in advance. The members of the class should observe the results and make the same entries in their notebooks as in a regular class exercise.

The successful teaching of chemistry requires efficient supervision of laboratory work and the teaching in the laboratory cannot be effectively accomplished without constant and untiring direction from the teacher. The more promptly a notebook description is corrected the more willingly will the student correct mistakes and wrong impressions, and thus the more effective will be the educational value of the work. A system which produces splendid results has been in use in

this laboratory for some time. The instructor passes from one student to another of his class reading the notebook descriptions and at the same time quizzing the owner upon any points which will reveal the student's understanding of the work he is doing. The advantage of the system is that the oral discussion permits the instructor to form a more definite opinion of the student's knowledge of the experiment than could possibly be gained by reading a written description, which the student frequently does not comprehend. It also renders unnecessary the weary hours spent in correcting notebooks at the end of the semester when the grade is the only thing which the student notices.

Another satisfactory plan is to require each student at the end of the laboratory period to hand in a page of his loose leaf notebook upon which he has recorded the work of the day; this should be corrected and returned to him at the beginning of the next laboratory period, at which time the student should be required to correct the mistakes of the previous period. An experiment should never be repeated until the student has determined his most probable source of error and devised a workable plan for avoiding the mistake.

The custom which prevails in some laboratories of calling in the notebooks at intervals tends to produce a careless spirit among the students, which is the more pronounced as the intervals are allowed to lengthen.

A few blank pages are scattered through the book. It may be found convenient to use these for memoranda, experimental data, or notes of various kinds. These pages are scarcely extensive enough to allow the student to make his complete record upon them. A separate notebook is essential.

A successful student of chemistry needs to possess a degree of manipulative skill. To that end suggestions in regard to correct manipulation have been grouped together in an introductory chapter. Constant vigilance on the part of the instructor is necessary to see that an operation is performed properly each time the student is called upon to perform it.

# LABORATORY EXERCISES IN CHEMISTRY

## CHAPTER I

### MANIPULATION

NOTE.—In beginning the study of chemistry it is very important to form correct habits in the laboratory. Wherever any operation is encountered for the first time, the student is urged to study thoroughly the paragraph which explains the correct method of carrying out that process. When the procedure is called for in later exercises he should *always* use the correct method.

**1. Pouring from a Beaker.**—In pouring a liquid from a beaker or evaporating dish into another vessel, a stirring rod

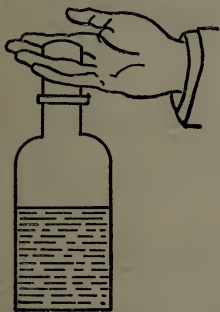


FIG. 1.

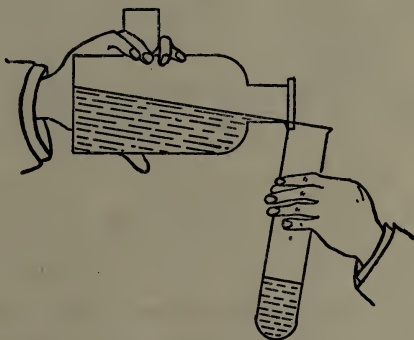


FIG. 2.

should be placed against the side in such a manner that the liquid will flow quietly down the rod and drop into the receiver without spattering (Fig. 5).

**2. Pouring from a Bottle.**—(a) In removing a stopper from a bottle take the stopper between the fingers as shown in Fig. 1. Hold the stopper between the fingers (Fig. 2) until you are ready to close the bottle. *Never lay a stopper on the table.*



(b) To pour a liquid from a bottle use a glass rod as in Fig. 5 or allow the neck of the bottle to touch lightly the side of the receiving vessel (Fig. 2). This precaution is especially important in the handling of acids since it prevents the acid from running back on the outside of the bottle.

(c) If it is desired to pour a few drops of a liquid from a bottle, it is best to wet the edge of the bottle, since the liquid is liable to come out with a rush if the edge is dry. Give the bottle a shake before removing the stopper, then draw the wet stopper out slowly, leaving a trail of liquid behind in the neck.

(d) When it is necessary to wet a stirring rod with a reagent, *never* put the rod into the bottle. Why? The rod may be



FIG. 3a.

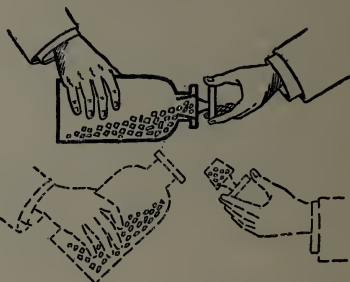


FIG. 3b.

wet by holding it over a sink and pouring a few drops of the reagent from the bottle; or, better, pour a few cubic centimeters of the reagent into a test-tube and dip the rod into it.

(e) If it is desired to pour a small amount of a solid from a bottle this may be accomplished by tilting the bottle and rotating it back and forth (Fig. 3a). If the stopper is hollow (the "mushroom" type), the result may be obtained by tilting the bottle until some of the solid falls into the stopper, then removing the stopper (Fig 3b) and taking as much material as required. If the residue in the stopper has not been contaminated with other chemicals it may be returned to the bottle. But *never return dirty or suspected material to a reagent bottle.* Why?

**3. Filtering.**—(a) *To Prepare a Filter Paper.*—Fold the paper along any diameter (Fig. 4), then once at right angles to the first fold. Open the paper so as to form a cone on one side of which there should be three layers and on the opposite side one layer. Fit the folded paper *smoothly* into a funnel,<sup>1</sup> then wet the paper with a few cubic centimeters of distilled water, which is allowed to run out before the material to be filtered is added. The filter paper should never reach quite to the top

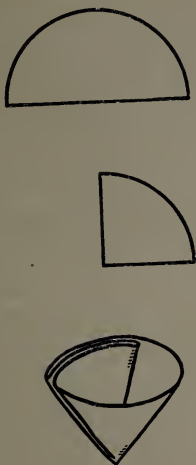


FIG. 4.

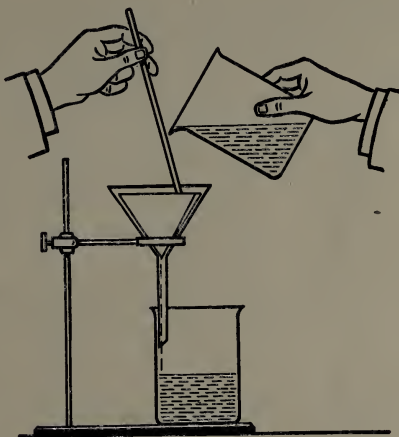


FIG. 5.

of the funnel and should never be filled entirely full of the material to be filtered. Why? Fig. 5 shows the correct method of filtering. Notice that the liquid runs quietly along the rod, down the side of the funnel and the beaker. It should not be allowed to fall in drops in the center of a beaker, or to spatter. The liquid which runs through the paper is called the *filtrate*; the solid on the paper is the *residue* or *precipitate*.

(b) When the precipitate is finely divided it may run through the paper. Generally the paper filters more effectively after

<sup>1</sup>Sometimes it is necessary to change the position of the fold slightly in order to do this, because the angle of the funnel is not accurately 60°.

a few moments than it does at first. In such cases refiltering the first portions through the *same* paper will correct the difficulty. Why? Sometimes heating the material before filtering will cause the precipitate to collect in larger grains which filter more easily. Occasionally it is necessary to use a double filter. This may be arranged by folding two papers separately and placing them in the funnel in such a position that the single fold of one paper is on top of the three layers of the other.

**4. Decanting.**—If a precipitate is heavy and settles well; it may be separated rapidly from the liquid by pouring the clear liquid away from the solid, a process known as *decantation*. This is a rapid method of separating a solid from a liquid, but complete separation is difficult to obtain in this way. If a quantitative separation is desired, it is necessary to decant through a filter. Why?



FIG. 6.

**5. Washing a Precipitate.**—If it is desired to wash a precipitate free from the mother liquor, this may be accomplished either by adding distilled water to the precipitate, shaking or stirring well and then decanting; or by bringing the precipitate on to a filter and directing upon it a stream of distilled water from a wash bottle. In each case *all* of the wash water in the filter must be allowed to pass through, before *any* additional water is added. Why?

**6. Use of Distilled Water.**—In preparing solutions for use in experimental work distilled water should always be used. Why? In washing apparatus wash first with tap water, and rinse with distilled water. Why?

The wash bottle shown in Fig. 6 is an indispensable article in the laboratory. Such a bottle should be furnished or should be prepared by each student. Always have a supply of distilled water on hand in the wash bottle. *Do not waste distilled water.*



### 7. The Use of Glass Tubing.—(a) *To Cut Glass Tubing.*—

With a triangular file make a scratch upon the glass at the desired point, then grasp the tube with both hands, and bring the thumb nails together directly opposite the file mark (Fig. 7). Press outward with the thumbs and pull gently with both hands. If the tube does not break readily make a deeper cut with the file, and extend it further around the tube. In the case of large tubing it is necessary to make a file mark entirely around the tube.

(b) “*Fire-polishing.*”—Before a glass tube or rod is used its sharp ends must be rounded by “*fire-polishing.*” This is done by rotating the end of the tube or rod in a Bunsen burner flame until the sharp edges become smooth.

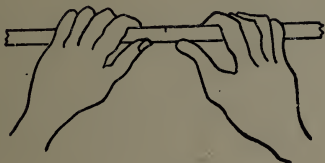


FIG. 7.

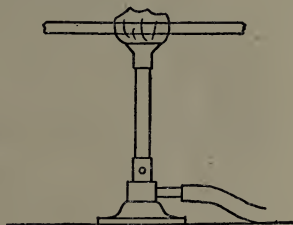


FIG. 8.

(c) *To Bend Glass Tubing.*—Attach to a Bunsen burner a “wing-top” and close the air holes, or use a flat “fish-tail” flame. Resting your elbows on the desk, hold the dry (why?) tube lengthwise in the flame (Fig. 8) and rotate it slowly, turning the tube always in one direction, *not* alternately one way then the other. Continue heating and rotating until the glass has softened, so that it will bend of its own weight, then *remove it from the flame* and promptly bend to the desired angle according to an angle marked on a piece of paper. If a right angled bend is desired, “square” the bend with the corner of the laboratory desk or a book. If the tube has been heated hot enough to burn off the deposit of carbon, it may be returned to the smoky part of the flame and rotated until a deposit of carbon forms. This permits the tube to cool slowly and is known as *annealing*. This is rarely necessary for small

tubes, however, if they are not allowed to touch a cold surface while hot. Support the tube so it will cool in the air. In Fig. 9 the bends *a* and *b* are correctly made, while *c* and *d* result from heating the tube through too short a distance or from using too great a force in bending the tube because it was removed from the flame too soon. The use of the latter tubes is not only unsatisfactory on account of the poor workmanship and the constricted bore, but it is also dangerous on account of the ease with which these tubes break.

(*d*) *To Make a Capillary or Jet*.—Hold a piece of tubing in both hands and heat it at the desired point in the upper part of a non-luminous Bunsen flame (*not* in a flat flame). Keep the tube rotating as in (*e*) until it is quite soft, then remove from the flame and pull the ends apart until the bore has the desired size. A jet or nozzle is made by cutting the capillary (*care*) and fire-polishing the end.

(*e*) *To Insert a Glass Tube in a Stopper*.—See that the tube is properly fire-polished (7(*b*)) and cold, then wet both the tube and the stopper. Push the tube through the opening in the stopper with a screw-like motion. If the tube is fragile or has a right angle bend, it is wise to protect the hand with a towel. Do not exert pressure on the *bend*.

If it is necessary to make a hole in the stopper, this may be done by the use of a cork borer. Select a borer slightly smaller than the tube, place the cork upon the table, with the small end uppermost, and by exerting a gentle pressure with a screw-like motion, drive the borer about halfway through the cork (Fig. 10). Then reverse the cork and from the opposite end bore in to meet the first hole. If the hole is too small, enlarge it slightly with a round file.

(*f*) *Softening Corks*.—Corks will fit more tightly if they are softened with a cork press before they are bored, or they may be softened by rolling them on the floor with the foot.

**8. Heating Material in Glass or Porcelain.**—In heating glass or porcelain remember that the temperature should be raised and lowered gradually. Why?

(a) *In a Test-tube.*—Substances may be heated in a test-tube by grasping the tube with a holder (Fig. 11a) or with a

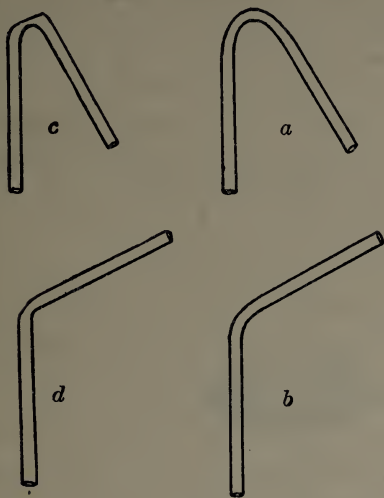


FIG. 9.

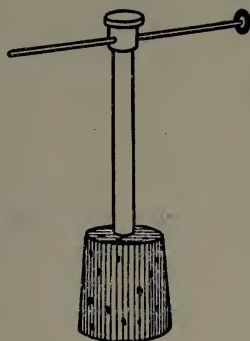


FIG. 10.

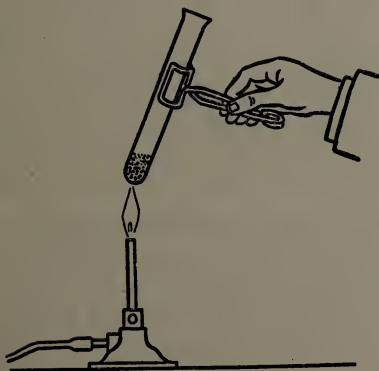


FIG. 11a.

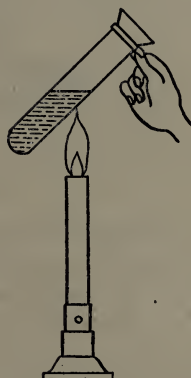


FIG. 11b.

folded strip of paper (Fig. 11b) and holding the tube in the upper part of the Bunsen flame. If the tube is full; begin by heating it gently throughout its entire length, so as to avoid

cracking. The sudden formation of steam within the tube may expel most of the contents, consequently a small quantity of liquid should be agitated while it is being heated. *Do not point the tube toward yourself or anyone else.* Why? Be very careful not to allow the flame to touch the tube above the level of the liquid. Why?

(b) *In a Beaker or Evaporating Dish.*—A beaker or evaporating dish should *never* come into direct contact with the flame but should be supported upon a wire gauze. Why? (Fig. 12).

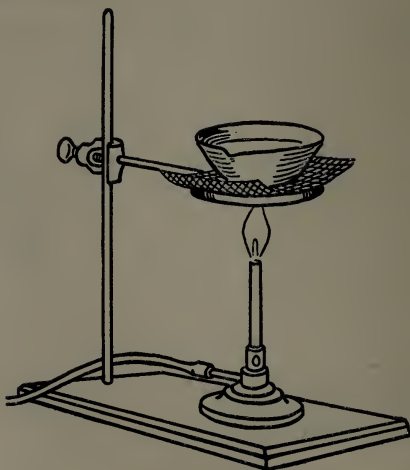


FIG. 12.

When a heavy liquid is being heated or a solution is being evaporated to dryness, spattering is frequent. Constant stirring will usually overcome this difficulty, or a low flame may be used, which will heat the liquid just below its boiling point.

**9. To Test for Leaks.**—In many experiments with gases, especially if quantitative results are required, it is necessary that all connections be free from leaks. In an apparatus like the gas burette (Fig. 15) close the opening in the burette and raise or lower the levelling tube and watch the meniscus in the

gas burette. If its position does not change appreciably for one minute, the apparatus is sufficiently air-tight.

An apparatus consisting of a flask or test-tube with a single delivery tube may be tested by closing the lips about the end of the delivery tube, sucking part of the air out of the apparatus and then touching the tongue to the end of the tube. If the tongue continues to cling after a minute or so, the apparatus is air-tight.

**10. The Use of the Balances.**—(a) *Approximate Weighing.*—All weighings except for quantitative experiments should be made on the platform balance on the side table. To weigh out non-corrosive solids, balance two weighing papers (filter papers may be used, but glazed papers are better) and then put the material on one paper and the weights on the other. Substances like sodium peroxide or sodium hydroxide should be weighed in glass or porcelain. To weigh such substances and all liquids, place a dish upon one side of the balance and a lighter dish such as a beaker upon the other. Pour into the smaller dish sand or shot until the two dishes are counterpoised, put the material to be weighed in the empty dish and weigh as usual.

*Never place chemicals directly on the scale platform.*

(b) *Accurate Weighing.*—The weight of materials to be used in the quantitative experiments must be determined by the use of the chemical balance. This is a delicate instrument and its use must be explained by an instructor.

To make a weighing, sit directly in front of the center of the balance and without raising the door release the scale pans by gently turning the knob at the bottom of the case. If the balance has separate supports for the pans and for the beams, first push in the button which releases the pans, then, very slowly, turn the knob which will allow the pointer to swing. If the pointer does not swing across the ivory scale, raise the stop and release again. The swing of the pointer should not extend beyond the graduations on the ivory scale. When the pointer is swinging freely, determine the "zero point" by



calculating the center of the swing of the pointer. Thus, if the pointer swings seven scale divisions to the right of the center line and on the same trip five scale divisions to the left, the zero point is one division to the right of the center line. This zero point must be determined before each weighing, since it is changed by many influences. In very accurate weighing the mean of two excursions to one side should be combined with one to the other. Thus if the readings are; right 4.3, left 5.4, right, 3.9, the true reading is  $\left(5.4 - \frac{4.3 + 3.9}{2}\right) \div 2 = 0.65$  to the left.

Open the door, place the object to be weighed on the left-hand pan (see Rule 3) and counterpoise it with weights (see Rules 3 and 4), beginning with the large weights and working down. *Never* allow the pointer to swing while an object or weight *is being placed* upon the balance pan. At first it is necessary to turn the knob only slightly until the direction in which the pointer moves indicates whether the weight is too light or too heavy. Arrest the beam and readjust the weights. Later it is necessary to entirely release the beam and note the swing of the pointer. When the combination of weights on the pan is almost equal to, but *less* than the weight of the object, close the door to the balance case, and adjust the rider upon the scale beam until the pointer swings about the same zero point as when the pans were empty. This indicates that both pans are carrying the same load. Determine the value of the load by counting up the weights on the pan and independently counting up the weights missing from the set. These sums should check. Observe the decimal system in the weights, thus 2 grams, 500 mg., 100 mg., 20 mg., 10 mg., and with the rider on 4.3, is recorded 2.6343 grams. Make this record in your notebook, *not* on a piece of paper. The beginner's most frequent mistake is in recording the weights in weighing. It is a good habit to read the weights first from the vacant places in the set and then to check the reading as the weights are removed from the scale pan. It is suggested that the

record be checked by an instructor before the weights are disturbed.

Finally remove the object, return each weight to its proper place, raise the rider and close the door.

Always observe the following rules in weighing on the chemical balance:

1. Handle the balance with care; failure to do so may result in financial loss or dismissal from the course.

2. The supports for the scale beams must be raised, preventing the swinging of the pointer, *at all times*, except the brief moments when they are lowered in the actual process of weighing.

3. Never put anything on the scale pans nor remove anything from them while the beam is swinging.

4. Handle the weights with forceps only; do not bend the small weights. Do not borrow weights from another balance case. There are always enough weights in one balance to weigh an object correctly.

5. *Never* place chemicals directly on the scale pans; first weigh a watch-glass or other small utensil, put the material in it and weigh again.

6. The scale pans should not be allowed to swing while the scale beam is released. Usually bringing up the supports will stop the swing.

7. Keep the pans and balance case clean; use the camel's-hair brush. Keep the balance shelf clean, also; use the larger brush.

8. If the balance seems to be out of adjustment, call an instructor. Never attempt to fix it yourself.

**11. Accidents.**—The most frequent accidents in the chemical laboratory are burns from handling hot pieces of apparatus and cuts from broken glass. It is especially important that cuts, even though slight, should be properly cleansed on account of the danger of infection. Report promptly to the instructor.

Most accidents may be avoided by observing the following precautions:

1. Remember not to handle hot apparatus.
2. In pushing a glass tube through a stopper protect the hand with a towel, and do not exert pressure on a bend.
3. Never light the gas from a hydrogen generator till you have tested the purity of the gas (24(d)). It is wise even then to wind a towel about the generator before igniting the gas.
4. Never look into the mouth of a test-tube or flask, especially when the contents is being heated.
5. If concentrated sulfuric acid is thrown on the face or hands wash it off immediately with a *copious* amount of water.
6. Dry sodium bicarbonate furnishes a good dressing for burns.
7. Red spots on clothing produced by acids may usually be removed by the application of a little ammonia.
8. Always breath through the nose and in short (not deep) breaths when chlorine or other poisonous gases are present. The vapor of alcohol gives relief after the accidental inhalation of chlorine or bromine.

*To the Teacher.*—In case of accidental burns, use the emergency bottles of sodium bicarbonate solution which are to be found at convenient places in the laboratory. In the halls are emergency cabinets equipped with material for first aid with directions for use. The following equipment is to be found in each cabinet:

Gauze bandage.

Scissors.

Sterilized gauze.

Eye glass.

Adhesive tape.

Spatula.

Absorbent cotton (do not put cotton into a wound; cover the wound first with gauze).

Alcohol (95 per cent.) for chlorine and bromine fumes.

Sodium bicarbonate solution for acid burns.

Soap solution (10 per cent.) for cleansing a wound.

Lysol solution (1 per cent.), antiseptic for cuts.

Carron oil, for application to burns.

Aristol, antiseptic dry dressing. Use sparingly as it is very expensive.

Boric acid, powdered, mild antiseptic.

Boric acid, solution, antiseptic for the eyes.



Solution, 2 per cent. boric acid, 4 per cent. borax, for burns.

Sodium bicarbonate, powdered, dry dressing for burns.

Carbolated vaseline, antiseptic dressing. Most serviceable for old wounds.

## CHAPTER II

### PREPARATION OF PURE SUBSTANCES— ELEMENTS AND COMPOUNDS

NOTE.—The textbook must always be brought to the laboratory and the record in the notebook should always begin with a reference to the pages in the textbook where the subject is treated.

**12. Distillation.**—(a) Put 5 grams of copper sulfate (blue vitriol) and 30 cc. of water in a 100-cc. flask. Take a glass

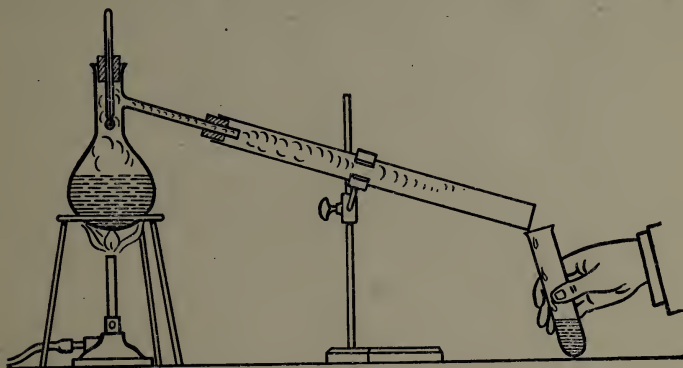


FIG. 13.

tube 15 to 20 cm. long and of 4 to 5 mm. internal diameter and bend it to an acute angle slightly less than a right angle (see 7(c)). "Fire-polish" the ends of the tube. Prepare a second tube 25 to 30 cm. in length and 10 to 12 mm. internal diameter. "Fire-polish" the ends. Select a cork that will fit the flask and another which will fit the larger tube. Soften the stoppers (7(f)) and bore holes in them to fit the bent tube (7(e)). Arrange the apparatus as shown in Fig. 13. Heat the solution to boiling and collect a few cubic centimeters of the

water which condenses in the larger tube. What tests might be applied to demonstrate that it is pure water? The warm tube should be set upright in a clamp and allowed to dry before it is used in (b).

Filter the solution of copper sulfate (3) into a small beaker and allow it to stand over night. Examine the solution at the beginning of the next laboratory period.

(b) *Dilute Alcohol*.—Mix 20 cc. of water (6) with 2 cc. of alcohol (2(a)(b)). Put a little of the mixture in a porcelain dish and test it with a flame to see if it will burn. Put the rest of the mixture into the flask and connect with the condensing tube as before. Distil and collect 1 cc. (not more(?)) in a dry test-tube. Test the distillate to see if it will burn (?).

**13. Crystallization.**—(a) *Copper Sulfate*.—If crystals of blue vitriol do not separate from the solution of 12 after standing over night, concentrate the solution by warming it to just below the boiling point on a support of wire gauze until about one-half of the solution has evaporated and set it aside again to crystallize.

(b) *Salt and Saltpeter*.—Take 5 grams (10(a)) of salt (sodium chloride), 15 grams of saltpeter (potassium nitrate) and 30 cc. of water in a beaker or flask. Warm on a wire gauze till the salts pass into solution. Filter, if the solution is not clear, and allow the filtrate to stand until cold and crystals separate. Larger crystals will be formed if the solution is allowed to remain perfectly still while crystallizing and this is better for our present purpose, though the small crystals obtained by rapid cooling and agitation are likely to be more pure. After crystallization has taken place, pour off the mother liquor into another beaker. Rinse the crystals two or three times with a *very little* water and then allow them to drain and dry on a piece of filter paper. Notice the form of the crystals and taste<sup>1</sup> one of them carefully. What are they?

<sup>1</sup> Many substances used in chemical laboratories are poisonous and nothing should be tasted unless there is specific direction to do so. In any case only a minute quantity should be used for tasting and this should be spit out as soon as the taste is made.





Concentrate the mother liquors by evaporating at a temperature just below boiling till some of the salt separates from the hot solution. Drain the hot mother liquors as completely as possible into another beaker and examine the crystals with a small lens if that is available, also taste them. A crop of crystals will be deposited from the mother liquors on cooling. Determine the nature of these(?) Under what circumstances can two substances be separated by distillation? By crystallization?

**14. Elements, Mixtures and Compounds, Formulas.—(a) Iron and Sulfur.**—Mix 7 grams of fine iron filings and 4 grams of sulfur intimately in a mortar. Examine some of the mixture with a lens(?). Pass a magnet through some of the mixture and blow away the sulfur. Put some of the mixture in a test-tube. add 3 cc. of carbon disulfide, shake, pour off the solution into a watch-glass and allow the carbon disulfide to evaporate(?) *Carbon disulfide is very inflammable and must not be brought near to a flame.*

Put the remainder of the mixture in a test-tube and while holding the tube in a nearly horizontal position apply a vigorous flame to the lower end of the tube till the mixture begins to glow. Remove the tube from the flame and notice the progress of the reaction through the mass. What is the source of the heat produced?

Allow the tube to cool, break it and examine the product in the same manner as the mixture(?). Are the particles of iron and sulfur visible, now? Can the iron and sulfur be easily separated? What has taken place?

From the amounts of iron and sulfur used, what is the formula of the compound? What is the formula of a compound which consists of seven parts of iron to eight parts of sulfur?

**(b) Mercuric Oxide.**—Take a piece of glass tubing 3 to 4 mm.<sup>1</sup> in internal diameter, and 7 to 8 cm. in length. Heat it in the flame, touch another piece of tubing or glass rod to it and draw it out so as to seal the end. Or a piece of tubing of

<sup>1</sup> See Appendix for metric equivalents.

twice the length may be heated in the middle and drawn out. Put a small amount of mercuric oxide in the tube and heat it. Test the gas which is evolved with a glowing splinter(?). What is formed besides the gas? What change of color is noted as the mercuric oxide is heated? What happens as the tube cools? What is the difference between an element and a compound?

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### CHAPTER III

#### OXYGEN AND COMBUSTION

**15. Catalysis.**<sup>1</sup>—Put a small amount (1 gram) of potassium chlorate in a 15-cm. dry test-tube. Place the tube in a clamp on the ring stand or hold it with a test-tube holder or with a piece of folded paper (8(a)). Heat the salt carefully over a Bunsen burner till it melts, but heat slowly enough so that bubbles of gas rise only very slowly through the liquid. Add a small amount of manganese dioxide and notice the effect. Keep the tube away from the eyes. Test the gas evolved with a glowing pine splinter.

Heat the mixture in the test-tube until the potassium chlorate is entirely decomposed. Allow the tube to cool until it can be held in the hand. Add 3 or 4 cc. of water and shake until the residue can be rinsed out into a small beaker. Allow the manganese dioxide to settle and pour off the solution into a porcelain evaporating dish. Evaporate the solution to dryness by heating the dish gently on an asbestos plate. Taste a *very little* of the residue and of the original potassium chlorate. What is the residue? How can you prove that it is not potassium chlorate?

Add some more water to the black residue in the beaker, allow the residue to settle again and pour off the liquid as com-

<sup>1</sup> Always read the portion of the textbook illustrated by the experiment *first*. Then read the experiment through and collect all the materials needed *before* beginning to carry out the directions. In this experiment, for instance, if the pine splinter is not ready at the proper moment the experiment will have to be repeated.







pletely as possible. With some more water rinse the residue into a porcelain dish. Pour off the water. Dry the residue by placing it upon a piece of filter paper. What is it? Prove by an appropriate experiment that it has the same properties as the material first used.

Explain how it could be demonstrated that the potassium chlorate has been changed while the manganese dioxide is the same as before by weighing the substances used and the products formed.

**16. Preparation and Properties of Oxygen.**—Take a glass tube 30 cm. long and bend it (7(c)) for a delivery tube as shown

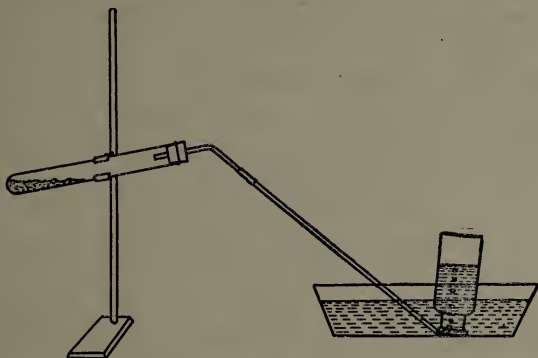


FIG. 14.

in the figure. Select a cork that will fit a 16- to 18-cm. tube of hard glass. Soften the cork by rolling it on the floor under the foot and bore a hole through it with a cork borer (Chapter I, 7(e)). Do this by boring only one-half way through from each end of the cork, so as to secure a clean opening from each end.

Put a mixture of 10 grams of potassium chlorate and 3 grams of manganese dioxide in the hard glass tube and arrange the apparatus for generating and collecting the oxygen (Fig. 14). The bottles to be filled with oxygen should hold about 500 cc. and each is to be filled with water, covered with a piece

of glass, paper or cardboard and inverted into a sink of water or a dish.

When all is ready the mixture in the tube is heated and four bottles are filled with oxygen. Each bottle as it is filled may be set upright and left closed with a piece of wet paper. The oxygen may be used for the following experiments:

(a) *Charcoal*.—Wrap a piece of copper or iron wire around a piece of charcoal about 1-cm. cube. Ignite the charcoal in the flame of a Bunsen burner and put it into the bottle of oxygen. *Do not drop* it into the bottle, for this will cause the bottle to break(?). When the combustion is complete put 10 cc. of water in the bottle, shake, and test the solution with blue litmus paper. Add 5 cc. of lime water and notice the effect. The precipitate formed is calcium carbonate, the same substance which is found in marble and limestone.

(b) *Sulfur*.—Burn about  $\frac{1}{4}$  gram of sulfur in a deflagrating spoon<sup>1</sup> in one of the bottles(?). *Do not drop* into the bottle. Put a little water in the bottle, shake and test the solution with blue litmus paper, also notice the odor. What property is shown by the change in color of the litmus? Add a drop of sulfuric acid to 50 cc. of water and test the solution with litmus paper, also taste a *drop* of the solution taken up on the end of a glass rod. Test some vinegar with blue litmus paper.

(c) *Phosphorus*.—With some forceps take a piece of phosphorus not more than 3-mm. cube and lay it for a moment on a piece of filter paper to remove the water adhering to it. Then put it in a deflagrating spoon, touch it with a file or piece of glass tubing which has been gently warmed in a flame and introduce it *at once* into one of the bottles of oxygen(?). Put some water in the bottle and test the solution with blue litmus paper(?).

*Phosphorus must always be cut under water and must be handled with forceps and not with bare fingers. If it takes fire*

<sup>1</sup> A piece of crayon, 15 mm. in length, slightly hollowed at one end and held by a wire wrapped around it and bent parallel to the length of the crayon furnishes a cheap substitute for the deflagrating spoon.





*in the fingers it produces painful burns which are difficult to heal. In case of an accident the fingers or hand should be thrust under water as quickly as possible.*

(d) *Iron*.—Wind a piece of iron wire into a spiral by wrapping it around a lead pencil or a piece of glass tubing. Heat the end and touch it to a small piece of sulfur or dip it in flowers of sulfur so that a small amount adheres to the wire. Ignite the sulfur and hold the wire in a bottle of oxygen(?). Does the oxide formed affect moist litmus paper? Do not be misled because the water in the bottle may have an acid reaction because of the sulfur used to ignite the iron.

What is the character of the light accompanying each combustion? Does the light come from the burning substance or from the product formed? Is it the same in all cases? Which of the substances burned are non-metallic? Which products give acids with water?

**17. Products of Combustion.**—Set a short piece of candle on the desk, light it, place over it a 500-cc. dry bottle and allow it to remain till the flame goes out(?). What is the deposit on the walls of the bottle? Is there any connection between the formation of this deposit and the temperature of the bottle? Put 5 cc. of lime water into the bottle and shake(?).

**18. Indestructibility of Matter.**—Take a not too thin-walled, dry, 500-cc. flask, put on the bottom a thin layer of dry asbestos and drop on this a piece of phosphorus about 3-mm. cube, handling this as directed under **16**, (c). Close the flask tightly with a solid rubber stopper and weigh the flask to an accuracy of 0.01 gram (**10(b)**). Heat the bottom of the flask carefully just under the phosphorus till it takes fire. When the flask has cooled to ordinary temperature, weigh again. Remove the stopper for a moment, replace it and weigh a third time(?).

**19. Law of Definite Proportion and Weight of a Liter of Oxygen.**—(a) Put about 0.3 gram (**10(a)**) of manganese dioxide in a 16 to 18-cm. hard glass tube and weigh to an accuracy of 1 mg., at least. Add 1 to 1.3 grams of potassium chlorate,

and weigh accurately a second time. Mix *thoroughly* the manganese dioxide and potassium chlorate by shaking. Arrange the apparatus used for preparing oxygen and heat the mixture till the oxygen has been expelled. Be careful to disconnect the hard glass tube from the stopper *as soon as* the heating is stopped and before it cools, as otherwise water may be drawn back into the tube as the oxygen in it cools and contracts. When the tube is cold weigh it again. What does the loss in weight represent? What per cent. is this of the weight of potassium chlorate used? What per cent. should it be according to the formula?

Place a gummed label on the bottle in which the oxygen has been collected across the line between the gas and the water. Make a mark at the line. Set the bottle upright and fill it to the line with water. Measure the volume of the water with a measuring cylinder. Take the temperature of the water with a thermometer and read the barometer. Find the vapor pressure of water at the given temperature from a table (see cover) and subtract this from the reading of the barometer(?) (Chapter VI. 28), calculate the volume which the oxygen collected would occupy at 0° Centigrade and a pressure of 760 mm. From this corrected volume and the weight of the oxygen as determined by the loss in weight of the potassium chlorate, calculate the weight of a liter of oxygen under standard conditions. Compare the result with the accepted value and determine the percentage error. Calculate also the weight of potassium chlorate required to give one liter of oxygen at standard conditions.

What law is illustrated by the fact that different members of the class obtain very nearly the same result for the per cent. of oxygen in potassium chlorate, if they work carefully?

Why is it necessary to allow for the vapor pressure of water in the gas? What would be the effect on the volume of the gas if this water vapor were removed from it? Why does not the fact that the ignition tube was full of air, some of which has gone with the oxygen into the bottle, vitiate the







result? What are some of the sources of error in the experiment? Do these tend to give a weight for the liter of oxygen which is too great or too small?

(b) Fit an ignition tube with a rubber tube and delivery tube so as to connect it with a gas burette. Put a *little* (0.1 gram or less) manganese dioxide<sup>1</sup> in the ignition tube and weigh the tube with the manganese dioxide accurately to 0.1 mg. Add 0.15 to 0.20 grams (not more unless the gas burette has a capacity of more than 50 cc.) of powdered potassium chlorate and weigh again. Mix thoroughly by shaking. Raise the side tube of the burette high enough so that the water comes nearly to the top of the burette and close the pinch cock at the top. Connect the hard glass tube with the top of the burette, open the pinch cock and read the volume of air in the burette (Chapter I, 9). The water in the side tube must be lower than the water in the burette for this test. After 1 minute read the volume again.

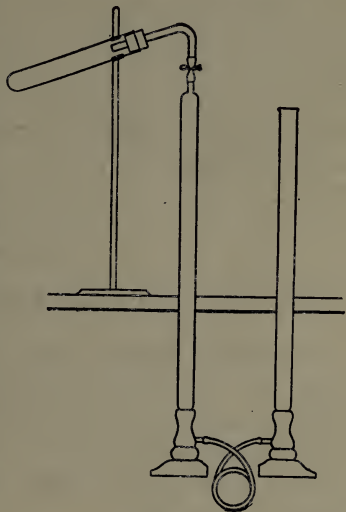


FIG. 15.

If there is no change, the apparatus is tight. If the level of the water in the burette has fallen, there is leakage and the rubber connection must be wired or the stopper pushed into the tube more securely and the test repeated till the apparatus is perfectly tight.

Hold the side tube in such a position that the water in that and in the gas burette are at the same level. Read the volume

<sup>1</sup> The manganese dioxide should be weighed approximately on the platform scales and put in the tube before going to the accurate balance. The potassium chlorate should also be weighed approximately on a piece of paper and taken to the balance room on this.

of air in the burette accurately, taking care to bring the eye to the level of the bottom of the meniscus of the water by bringing this between the eye and some distant object at the same level. Record this reading. Set the side tube on the table and heat the mixture of potassium chlorate and manganese dioxide till the chlorate is completely decomposed. When the tube has cooled, read the volume of gas in the burette as before, and repeat the reading after 3 to 5 minutes to make sure that the tube is really cool and the volume constant. Take the temperature of the air beside the burette and read the barometer. Weigh the tube again and determine the weight of the oxygen, which has been expelled from it. Complete the calculations as directed under (a).

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## CHAPTER IV

### LAWS OF GASES—WEIGHT OF A LITER OF AIR

**20. Law of Boyle.**—Select two tubes respectively of 4 to 5 mm. and 9 to 12 mm. internal diameter, 700 to 900 mm. in length and closed at one end. Measure the length of the interior of the smaller tube. In the following calculations the volume of the tube may be considered as proportional to its length.

Fill the larger tube one-half to two-thirds full of water, set it upright and insert the smaller tube far enough so that its end is 250 to 300 mm. from the bottom of the larger tube. Handle the smaller tube with a handkerchief, towel or test-tube holder to prevent warming it with the hand(?). Insert a wooden wedge between the two tubes to hold the smaller tube in place. This must be done carefully or the larger tube will be broken. If a test-tube holder is used this may rest on the edge of the larger tube. Measure in millimeters the length of the column of air in the smaller tube and the distance from the level of the water in the smaller tube to the level in the larger tube.

The specific gravity of mercury is 13.6. If the distance





between the two levels is divided by this number it is evident that we shall have the number of millimeters of mercury which would produce the same additional pressure upon the air in the small tube as that which is exerted by the water. Read the barometer. From the measurements made verify the law of Boyle.

Push the smaller tube to the bottom of the larger one and repeat the measurements and calculations.

**21. Law of Charles.**—Fit a 300-cc. flask with a tightly fitting rubber stopper through which passes a short piece of glass tubing which has at its end a short piece of flexible rubber

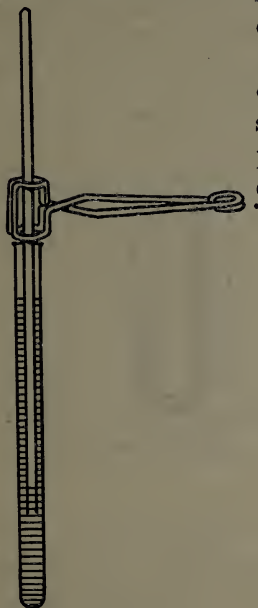


FIG. 16.

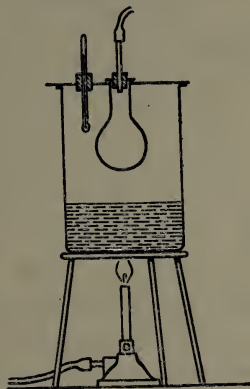


FIG. 17.

tubing. Everything must be dry. Weigh the flask and stopper to an accuracy of 0.1 gram on the platform scales. Take a tin can or small lard pail of such size that the flask may be suspended inside. Cut a slot in a flat piece of sheet tin in such a manner that the neck of the flask will just pass into it and the flask may hang in the slot by its lip and be suspended in the middle of the pail or can. Make another hole in the tin and suspend a thermometer in this. Put water in this can and

when all is adjusted and the slot covered with a piece of tin, heat the water to boiling and boil till the thermometer remains constant for some minutes(?). Pinch the tube tightly with the fingers, remove the flask from the can by raising the lid, take hold of it with a towel or test-tube holder and transfer it, bottom side up, to a beaker of water, opening the rubber tube beneath the surface of the water and allowing water to enter as the flask cools. Immerse the flask completely beneath the water, with its mouth downward, till it is cooled, then hold it for a moment with the water on a level within and without

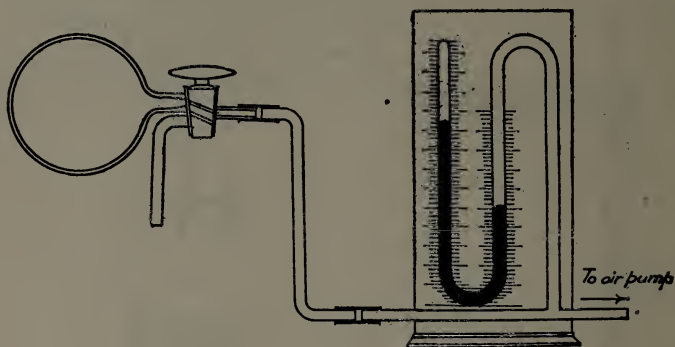
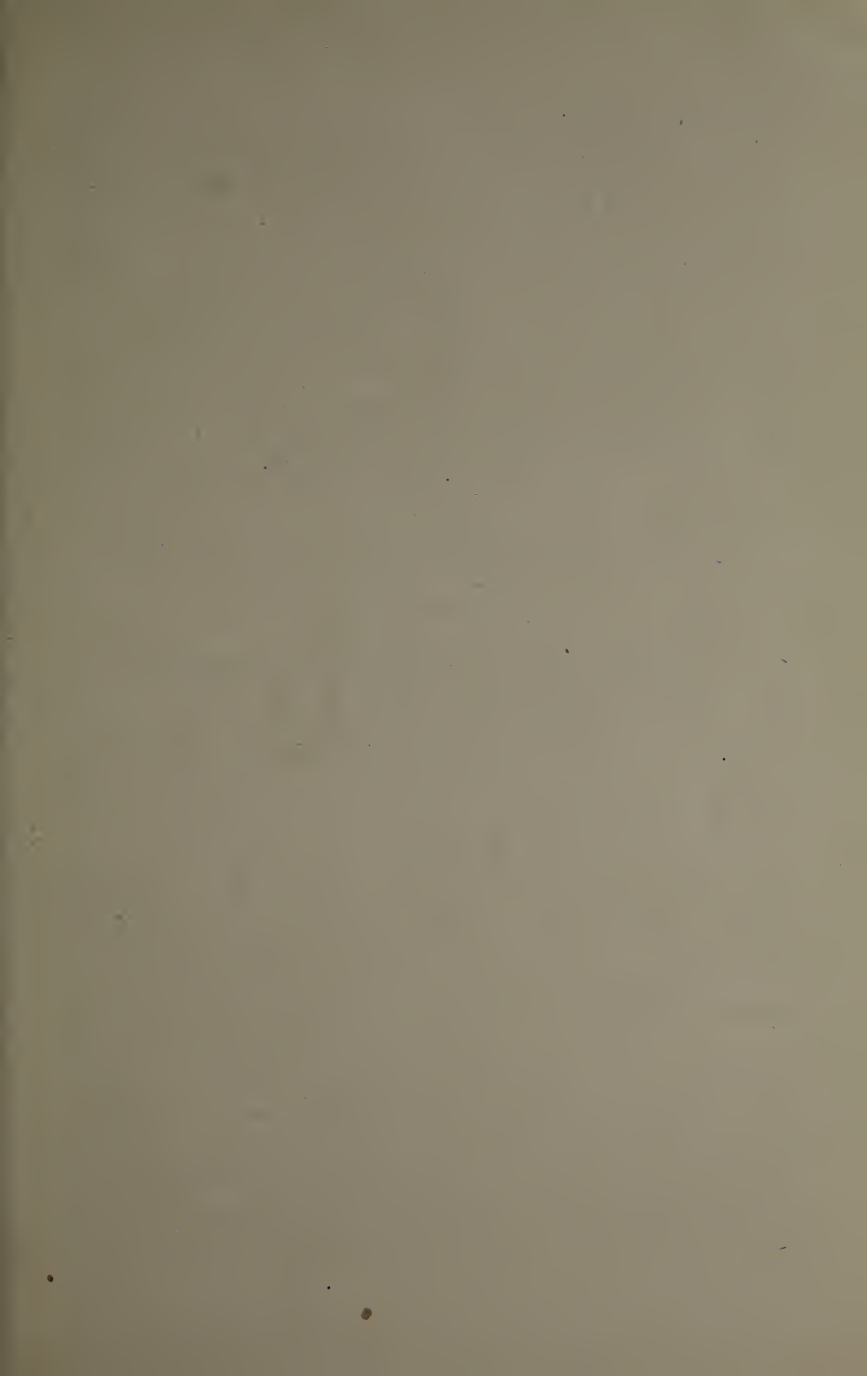


FIG. 18.

the flask. Pinch the tube tightly again and set the flask upright. Take the temperature of the water. Dry the outside of the flask with a towel and weigh it. Fill it completely with water and weigh a third time. Calculate the volume which the air at the higher temperature should occupy when cooled to the lower temperature and compare this with the volume found. What is the percentage error?

**22. Weight of a Liter of Air.**—Connect a bulb having a known<sup>1</sup> volume of 125 to 150 cc. with a manometer and air

<sup>1</sup> The volume may be obtained by weighing the bulb full of air and then full of water (see Noyes, Textbook of Chemistry, p. 73). The bulb must be thoroughly dried afterward by warming it and evacuating before it is used for the determination.







pump as shown in Fig. 18. Exhaust to a pressure of 100 mm. or less. Close the stop-cock after reading the pressure accurately. Read the temperature with a thermometer. Calculate the volume which the air remaining in the bulb would occupy under standard conditions ( $0^{\circ}$  and 760 mm.). Weigh the bulb accurately. Open the stop-cock and weigh again. Take the temperature of the balance case and read the barometer. Calculate the volume which the air in the bulb at the second weighing would occupy under standard conditions. Calculate the weight of one liter of air from the results. Compare with the weight given in the textbook, giving the page in the textbook where the weight is to be found.

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## CHAPTER V

### HYDROGEN

**23. Preparations of Hydrogen.**—(a) *By Sodium.*—Put 10 cc. of water in a small beaker and throw a piece of sodium about 2-mm. cube on its surface(?). *Notice the difference between sodium and phosphorus in the precautions necessary in handling it. Sodium is kept under kerosene and must not come in contact with water or wet fingers.* Put a small piece of filter paper on the surface of the water and lay on this another piece of sodium of the same size(?). Explain the difference. Test the solution in the beaker with red litmus paper. Taste a drop of the solution on the end of a glass rod. Compare with the properties of 10 cc. of water to which one drop of a solution of sodium hydroxide has been added. Also recall the results with acid solutions.

(b) *By the Action of Water on Iron.*—Fit a 100-cc. flask with a thistle tube and a delivery tube as shown in Fig. 19. With a blast lamp draw out a piece of hard glass tubing which is 20 cm. in length and bend the portion drawn out at right angles. Fit the other end with a perforated cork stopper connecting it with the delivery tube of the flask. At the other end con-

nect it with a tube which will deliver the hydrogen under the surface of the water in the dish. Put 2 or 3 grams of iron filings near the upper end of the tube, heat these red hot and then heat the water to boiling. Some water will condense in the lower part of the hard glass tube and if this is allowed to come in contact with the heated portion it will surely be broken. After the air has been expelled, collect the hydrogen generated in a small bottle or test-tube and test it with a flame. Explain why the hard glass tube is slanted upward instead of downward; also, why the thistle tube is used in the bottle which furnishes steam. What is the essential difference in the com-

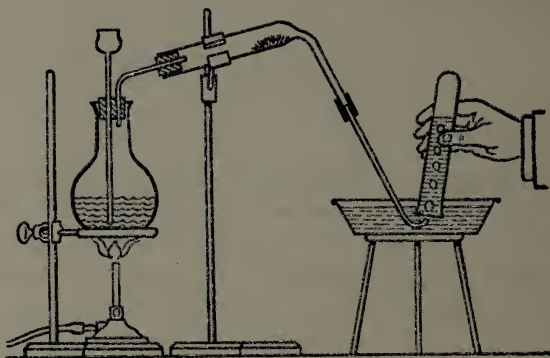


FIG. 19.

position of the products formed by the action of the water on sodium and on iron? What per cent. of hydrogen is liberated from a given weight of water in each case?

(c) *By the Action of Acids on Metals.*—Put 1 gram of iron filings in a test-tube, add 1 cc. of dilute hydrochloric acid and test the gas evolved with a flame(?). Repeat, using zinc and dilute sulfuric acid. What products remain in solution in each case? Try also copper and dilute sulfuric acid and tin with dilute and also with concentrated hydrochloric acid.

**24. Properties of Hydrogen.**—*Caution: Be very careful not to bring a flame near to a hydrogen generator so long as it may*





contain an explosive mixture of air and hydrogen (11(3)). Fit a 200-cc. bottle with a cork bearing a thistle tube and delivery tube as shown in Fig. 20. Put 10 grams of zinc in the bottle and enough water to cover the end of the thistle tube. Pour dilute sulfuric acid into the thistle tube in small portions and fill three or four bottles having a capacity of 200 to 300 cc. with hydrogen by displacement of water. Do not use the first bottle collected(?). Use the second for (a)

(a) *Lightness*.—Raise one of the bottles from the water and pour the hydrogen from it *upward* into another bottle. Set the first bottle upright on the desk and the second bottle

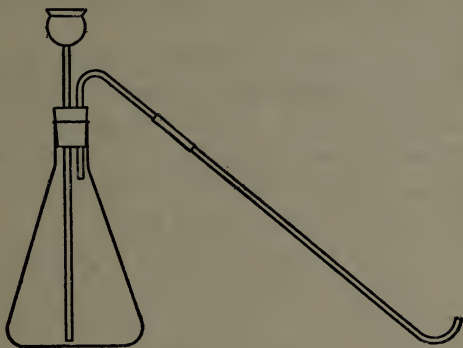


FIG. 20.

with its mouth downward. Test each with a lighted match or flame. Explain.

(b) *Effect on Combustion*.—Holding a bottle of hydrogen with its mouth downward apply a lighted candle supported by a wire, or a long burning splinter to the mouth of the bottle and then thrust it upward into the gas(?). The candle may usually be relighted by withdrawing it slowly past the point where the hydrogen is burning in contact with the air.

(c) *Explosiveness*.—Fill a 100-cc. wide-mouthed bottle two-fifths(?) full with hydrogen and the remainder with air, but leaving a little water in the bottle. Place a piece of paper over the mouth of the bottle and shake it to mix the gases.

Then apply a flame. Explain the difference between the conduct of hydrogen in this and in the preceding experiment.

(d) *Burning, Product of Combustion.*—Add some more acid to the generator and collect a test-tube full of the gas by displacement of air, leading the gas at first to the upper end of the test-tube and slowly raising the tube away from the delivery tube. Light the gas in the tube at a flame which is at least 2 feet from the generator and if the hydrogen continues to burn at the mouth of the test-tube light the gas issuing from the delivery tube by means of this burning hydrogen. *The hydrogen issuing from the delivery tube of a generator must never be lighted by any other method(?)*. Notice the color of the flame at first and later(?).

Hold a cold, dry beaker, or bottle over the burning jet of hydrogen(?) What additional experiments would be needed to identify the deposit on the glass? How could the composition of the deposit be more completely demonstrated? What previous experiment has demonstrated the presence of hydrogen in the substance which is formed here?

(g) *Diffusion.*—Fit a small cylinder of unglazed porcelain with a stopper bearing a narrow tube 20 to 25 cm. in length. Place the end of this in a beaker or dish of water and bring a bottle of hydrogen over the cylinder(?). After a minute or so remove the bottle(?).

Place a 100-cc. wide-mouthed bottle filled with hydrogen with its mouth downward on an upright bottle of the same size. After 10 minutes test the contents of each bottle with a flame, testing the contents of the lower one immediately after removing the upper one.

**25. Reduction by Hydrogen**—(a) *Copper Oxide.*—Put a little (0.3 to 0.5 gram) copper oxide in a narrow glass tube 15 to 20 mm. in length. Connect this with a generator and light the hydrogen coming from the end of the tube by the method described in (d)(?). Heat the copper oxide(?) gently and notice any deposit in the tube beyond the point heated(?). Does the flame of hydrogen at the end go out? Why?







(b) *Oxide of Iron—Reversible Reactions.*—Repeat (e) using magnetic oxide of iron in place of copper oxide. Is the result consistent with method (b) for preparing hydrogen? Explain.

**26. Rate of Passage of Hydrogen through a Small Opening.**

—Take a rather long, narrow-mouthed, 100-cc. plain bottle. Make a deep scratch near the bottom with a sharp file or glass cutter. Apply to this scratch, first at one end, and then, quickly, at the other, an iron rod, 6 to 9 mm. in diameter, which has been heated red-hot in a flame. This will usually start a crack in the glass which may be led around the bottle by keeping the hot iron just in front of the crack as it progresses. After cutting off the bottom of the bottle in this manner round off the sharp edges with a file.

Take a piece of glass tubing of 4 to 6 mm. internal diameter, warm it in the flame about 6 cm. from the end (7(d)) and draw it out to a capillary. Cut it off with the file and narrow the end to a *very* fine opening by beating it cautiously in the flame. Make sure that the fine opening has not been closed entirely by the heating. Select a cork to fit the neck of the bottle, soften it as usual and perforate it with a hole to fit the tube. With

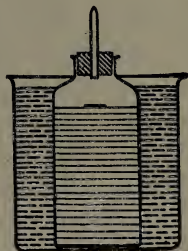


FIG. 21.

a moist file, best a round one, make a mark on the side of the bottle 1 cm. below the shoulder. The mark may be made clearer with a lead pencil or blue glass-marking pencil.

Fill a large beaker or dish with water to such a depth that when the bottle is placed on the bottom the water will just cover the shoulder of the bottle. Insert the stopper bearing the glass tube into the mouth of the bottle, bring the bottle quickly to the bottom of the beaker, note the time required for the air in the bottle to escape through the narrow opening so far that the water rises to the mark on the side of the bottle. If the time is 1 minute, or longer, the opening is of proper size. If the time is less, the opening must be further reduced in size. When an opening of proper size has been secured, deter-

mine as accurately as possible the time required for the air to escape from the bottom of the bottle to the mark on the side. A series of three or four observations differing from each other by only a few seconds should be secured and the mean of these taken.

Now place the bottle in the beaker, insert the stopper bearing the tube and fill the bottle with hydrogen by displacement of the water. Determine the time required for the hydrogen to escape and repeat till two or three concordant observations are secured.

Repeat the experiment with carbon dioxide.

The time required for a gas to escape through a small opening (not through a narrow tube) varies as the square root of its density. Assuming hydrogen as 1, calculate the density of air and of carbon dioxide by means of this rule and compare the result with the densities of the gases calculated from the weight of 1 liter of each gas. Is there any connection between the densities of the gases and the molecular weights calculated from the formulas?

**27. Valence.**—Prepare a glass tube 4 to 5 mm. inside diameter and 15 to 20 mm. in length, sealed at one end. Close this with a small plug of cotton and weigh it accurately. Put 0.03 to 0.04 grams of sodium<sup>1</sup> in the tube, replace the plug of cotton and weigh again. Fill a test-tube which holds 20 to 30 cc., with water and invert it with the mouth under water in a small porcelain dish. Remove the plug of cotton from the tube containing the sodium and thrust the mouth of the tube containing the sodium beneath the mouth of the test-tube. If the operation is performed correctly, all of the hydrogen generated will collect in the test-tube. Place the thumb over the end of the tube with care not to admit air. Measure the water remaining in the tube. Fill the tube with water, place the thumb

<sup>1</sup> Pieces of sodium of the proper size should be cut by the instructor before the exercise and kept in a dish covered with kerosene. The student should take out a piece with dry forceps and lay it on a piece of filter paper for a moment before putting it in the tube.





over the end as before and measure the water which the tube contains when full. The difference will be the volume of the hydrogen. Take the temperature and barometric pressure as usual and find the corrected volume of the hydrogen. Calculate from the data obtained the volume of hydrogen liberated by one milligram atom of sodium.

Weigh 0.02 to 0.03 gram of clean magnesium ribbon accurately. Fill a test-tube with water and invert it in a small porcelain dish. Fold the ribbon compactly and slip it under the edge of the test-tube. Pour a little concentrated hydrochloric acid down the side of the dish and wait till the magnesium is completely dissolved. Repeat the same measurements and calculations as with sodium.

Weigh 0.015 to 0.02 gram of aluminium wire and repeat the same experiment as with magnesium, using a 40 per cent. solution of sodium hydroxide in place of hydrochloric acid. The acid might be used but a stronger acid is required and the action is usually slow. To avoid putting the fingers into the solution containing alkali, after the aluminium has dissolved transfer the porcelain dish to a sink or large dish containing water, remove the dish, and after the heavy alkaline solution has fallen out of the tube place the thumb over its mouth and complete the measurements as before.

Explain how the results illustrate the principle of valence.

**274. The Equivalent Weight of Magnesium.**—Arrange the apparatus according to Fig. 21*a*, using an ordinary test-tube as the generator and an inverted 100-cc. graduated cylinder as the gas collecting burette.

Place a weighed strip of magnesium ribbon in the test-tube and fill the entire apparatus with water. (The magnesium ribbon should not weigh more than 80 milligrams. If the weight per centimeter is known, a definite length of the ribbon may be measured off and its accurate weight calculated from this.) All of the air can be expelled from the apparatus only by keeping the stem of the funnel filled with the liquid all the time. This can be done by closing



the pinch-cock, filling the funnel with liquid and allowing only portions to run into the test-tube by opening the pinch-cock a little at a time. After all air has been expelled

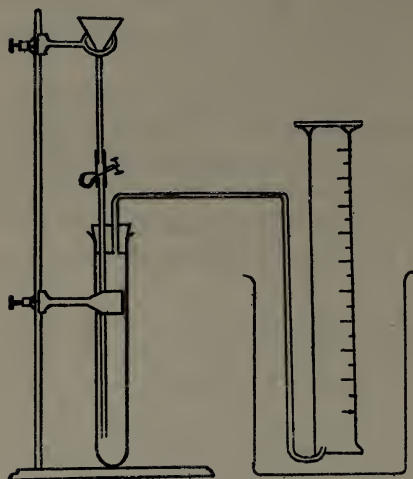


FIG. 21a.

introduce 20 cc. of diluted hydrochloric acid into the funnel and allow it to run into the test-tube by the method described above. The gas generated can then be driven into the eudiometer by pouring in more water. Bring the gas to atmospheric pressure (how and why) and read the volume, noting the temperature of the room and the atmospheric pressure. Should any correction be made

for vapor pressure? Calculate the weight of hydrogen evolved and the weight of magnesium required to give one gram of hydrogen.

## CHAPTER VI

### WATER. HYDROGEN PEROXIDE

**28. Vapor Pressure of Water.**—Fit a 500-cc. narrow-necked bottle with a tightly fitting rubber stopper bearing a straight glass tube, *A*, reaching nearly to the bottom of the bottle and a bent tube, *B*. Connect *A* with a tube, *C*, containing calcium chloride and draw air slowly through the bottle till it is thoroughly dry. Connect *B* with the T-tube, *D*, which bears at the top a flexible rubber tube which may be closed with the pinch-cock, *F*, also a U-tube, *E*, which contains some water. Select a tube, *G*, which will pass easily into *A* and is a little longer than





that. Draw it out to a fine capillary at one end and fit the other end with a rubber tube through which passes a glass rod, *H*, fitting closely. Fill this tube with water and insert the glass rod. Wipe off the outside of the tube so that there is no moisture on it. Remove the calcium chloride tube and insert *G* in its place far enough so that the point comes to the lower end of *A*. Open the pinch-cock at *F* for a moment so that the water will stand level in the two arms of the U-tube. Push the rod *H* down to force some water out into the bottle and draw it back to its original position. When equilibrium between the liquid water in the bottle and the vapor of water in the air above it is reached, what should be the difference between the levels of the water in the two arms of the U-tube?

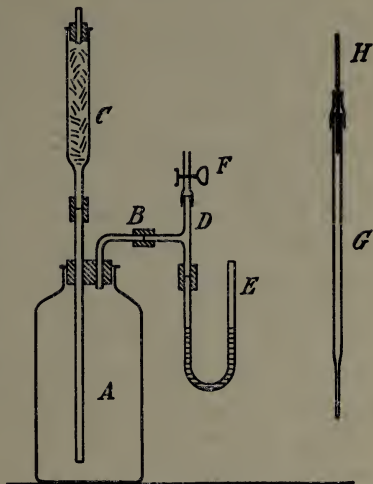


FIG. 22.

**29. Solutions.**—Put in a test-tube a gram of salt, in a second a gram of powdered copper sulfate, and in a third a gram of calcium sulfate. Add 5 cc. of water to each and shake vigorously. If any one of the substances does not dissolve, carefully pour some of the liquid above the undissolved substance into a watch-glass and evaporate it to dryness to determine whether anything has passed into solution. What are the terms employed to designate the solid substance used, the liquid, and the product formed by bringing the two together?

**30. Supersaturated Solutions.**—Take 5 grams of crystallized sodium sulfate,  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  and 6 cc. (not more) of water in a test-tube and warm and shake, holding it in a

beaker of water kept at  $30^{\circ}$  to  $32^{\circ}$  until the salt is *completely* dissolved. Close the tube with a tuft of cotton to protect it from dust(?) and set it in a beaker of cold water ( $20^{\circ}$  or under) for a few minutes, then drop into the tube a minute crystal of the sulfate(?). *Define a saturated solution.* What is the difference between the two expressions "a solution which contains all of the solute which the solvent will dissolve when in contact with the solid solute," and, "a solution which contains all of the solute which the solvent can hold in solution?"

**31. Efflorescence and Deliquescence.**—Expose some crystals of sodium sulfate,  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ , a little powdered calcium chloride and some crystals of copper sulfate (blue vitriol) on watch-glasses, or a piece of glass, to the action of the air of the laboratory for some time(?).

**32. Water of Hydration.**—Weigh a porcelain crucible accurately. Put into it about 1 gram of gypsum(?) and weigh it again. Support the crucible on a triangle and heat it for 5 minutes nearly to redness. Cover it with a watch-glass or crucible cover and allow it to cool. Weigh it again and calculate from the result the per cent. of the water of hydration in gypsum. Compare with the theoretical per cent.

Heat one gram of each of the following substances in a dry test-tube and notice whether water is given off and condenses on the walls of the tube. Copper sulfate, sodium chloride, sodium phosphate, potassium dichromate. Which of these are hydrates?

**33. Hydrogen Peroxide.**—(a) *Preparation.*—Put 5 cc. of dilute sulfuric acid into 50 cc. of water. Weigh 1 gram of sodium peroxide on a watch-glass (not on paper for sodium peroxide may cause the ignition of organic matter). Add this gradually to the dilute acid, stirring vigorously. The solution should have an acid reaction. If it has not, add more dilute acid till the reaction is acid toward litmus paper. Write the equation. What does the solution contain besides hydrogen peroxide?

(b) *Oxidizing Properties.*—Take one or two drops of a solution of lead acetate or lead nitrate in 10 cc. of water, add one







drop (not more) of ammonium sulfide or a few drops of a solution of hydrogen sulfide(?). Put a little of the black precipitate suspended in water into another test-tube and add some of the solution of hydrogen peroxide(?). Write equations.

(c) *Reducing Properties.*—To 10 cc. of the solution of hydrogen peroxide add a few drops of a 1 per cent. solution of potassium permanganate,  $\text{KMnO}_4$ . If a gas is evolved in sufficient quantity, demonstrate its nature. Write the equation for what occurs. How can hydrogen peroxide be both an oxidizing

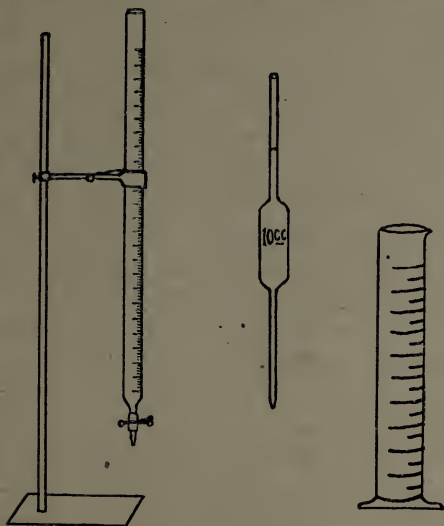


FIG. 23.

and a reducing agent? Which sort of a substance is potassium permanganate?

(d) *Determination of the Amount of Hydrogen Peroxide.*—Prepare a solution of 1.58(?) grams of potassium permanganate in 500 cc. of water. This is done most easily by putting the permanganate in a flask, adding 25 cc. of water and heating it to boiling for a short time. Pour the solution into a larger quantity of water, noticing whether any crystals of the permanganate have remained in the flask undissolved. If this is

the case, add some more water, heat again and repeat till the salt is completely dissolved. Put the solution in a measuring flask or measuring cylinder and make the volume up to 500 cc. by adding water. Mix thoroughly and put some of the solution in a burette, filling it a little above the zero mark. Draw out some of the solution by opening the stop-cock at the bottom until the upper line of the solution in the burette is exactly at zero. Measure 10 cc. of the hydrogen peroxide solution into a beaker. Add 1 to 2 cc. of dilute sulfuric acid and run in the permanganate solution from the burette as long as it is decolorized. Stir constantly with a glass rod. With care the end of the reaction can be determined with a single drop. Calculate from the results the total amount of hydrogen peroxide in the original 50 cc. of the solution which was prepared; also what percentage this is of the amount of hydrogen peroxide which should have been formed from 1 gram of sodium peroxide.

These calculations may be carried out in the following steps:

1. What weight of available oxygen does 1.58 gram of potassium permanganate contain?

2. What weight of available oxygen does 1 cc. of the permanganate solution contain?

3. What weight of oxygen was used by 10 cc. of the solution of hydrogen peroxide?

4. What weight of hydrogen peroxide is equivalent to this weight of oxygen in the reaction?

5. From this calculate the total weight of hydrogen peroxide in 50 cc. of the solution and compare this with the weight of hydrogen peroxide which one gram of sodium peroxide should give.

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## CHAPTER VII

### CHLORINE

*Caution.*—Chlorine is poisonous and it must never be allowed to escape into the open air of the laboratory. Always work with it in a hood or near a draft-flue. If breathed, chlorine attacks





*the mucous surfaces of the respiratory tract and produces the effect of a cold. The best antidote is to breathe the vapor of strong alcohol placed on a handkerchief.*

**34. Electrolysis of a Solution of Salt.**—Fill the U-tube shown in Fig. 24 within 1 cm. of the stoppers with a 10 per cent. solution of common salt(?). The U-tube should have an internal diameter of 12 to 15 mm. and should be 12 to 15 cm. high. The corks have carbon rods about 5 cm. in diameter passing through them and reaching nearly to the bottom of each arm of the U-tube. A small notch about 3 mm. in diameter is cut lengthwise in each cork to allow the escape of the gases. Attach the wires of a storage battery giving a potential of about 6 volts (3 storage batteries or 4 dry cells) to the carbon electrodes for one minute, or the arrangement set up in the laboratory may be used. At the end of that time apply a lighted match to the opening in the cork whence the gas is escaping most freely and notice the odor, cautiously, on the other side. Remove a little of the solution from each side with a glass rod and test it with litmus paper.

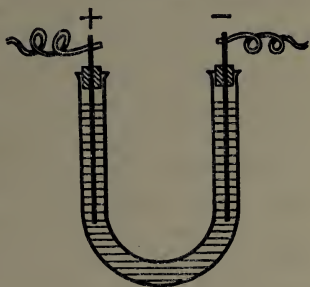


FIG. 24.

Also test the original salt solution both with blue and with red litmus paper. Explain all of the phenomena, (color, etc.), looking further on under the properties of bases and of chlorine to account for a part of them. Recall the results of 23(a).

**35. Preparation of Chlorine.**—What substances have been used in previous experiments to generate oxygen? What substance has been used as an oxidizing agent? Put a *very little* (0.1 gram) of each of these substances in separate test-tubes, add a few drops of concentrated hydrochloric acid and test the gas liberated for chlorine, with potassium iodide starch paper. This is prepared by dipping strips of paper into starch paste which contains a little potassium iodide. The

chlorine combines with the potassium and liberates iodine and the latter forms a blue compound with the starch. Test the gas also with moistened blue litmus paper. Notice two changes in color and explain these.

*As soon as the tests have been made rinse out the tubes with a copious amount of water.*

**36. Properties of Chlorine.**—Prepare a 50-cc. flask with a stopper and delivery tube bent twice at right angles. The tube should be long enough to reach to the bottom of the bottles used to collect the chlorine. Put 3 grams of potassium permanganate in the flask. Add 10 cc. of concentrated hydrochloric acid. This is best measured into a test-tube so that it may all be added quickly. Insert the stopper bearing the delivery tube immediately and fill two or three 200-cc. bottles with the chlorine generated. Cover the bottles with pieces of cardboard or with glass plates. Why are the bottles placed upright on the table instead of inverted, as is done in collecting hydrogen by displacement of air? What is the weight of a gram-molecular volume of chlorine? Of air? What is the density of chlorine referred to air?

It may be necessary to warm the flask gently to furnish chlorine enough to fill the three bottles required for the following experiments. As soon as the generation of the chlorine is complete open the flask in a hood or near a good draft and fill it with water, then empty it into the slopjar and rinse out the flask.

(a) *Antimony and Chlorine.*—Sift a little finely powdered antimony into one of the bottles(?).

(b) *Hydrogen and Chlorine*—Lower a small jet of burning hydrogen into a bottle of chlorine. The hydrogen is best drawn from a Kipp generator and should be burned at the end of a small tube bent horizontally a short distance from the end, so that the jet may be lowered to the bottom of the bottle. Lower the jet slowly as the color of the chlorine disappears(?). Test the gas in the bottle with moist blue litmus paper and compare with the effect of chlorine on litmus







paper(?). Notice the odor of the gas *cautiously*. For this purpose a little of the gas may be thrown toward the nose from the mouth of the bottle with the hand. Add 10 cc. of water to the contents of the bottle and taste a drop of the solution on the end of a glass rod(?).

(c) Put a piece of phosphorus about 2-mm. cube (see 16(c)) in a bottle of chlorine. Notice whether liquid phosphorus trichloride or solid phosphorus pentachloride is formed. Add a few drops of water and note the effect on the chloride(?).

(d) *Effect of Chlorine on Colors.*—Hang from opposite sides of a bottle of chlorine two narrow strips of bright calico, one dry, the other wet(?).

**37. Chlorine by the Deacon Process.**—Moisten some asbestos with a solution of copper chloride and dry it in a porcelain

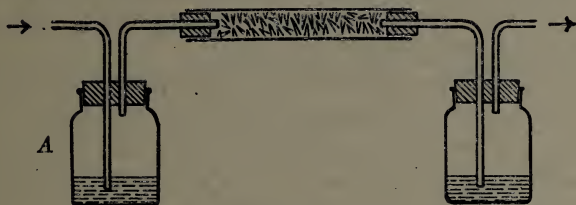


FIG. 25.

dish. Prepare a tube 10 to 13 mm. in diameter and 20 cm. in length with perforated stoppers bearing short glass tubes. Connect this with two wash bottles, one, A, containing 10 cc. of concentrated hydrochloric acid and the other 20 cc. of a 1 per cent. solution of potassium iodide. Draw air through the system in the direction of the arrow. A faint yellow color may develop from the action of air on the acid solution of potassium iodide, but this will be very different from the effect produced in the second part of the experiment. Now heat the tube containing the copper chloride and continue the current of air through the system. Explain the result. What would be the effect of passing a current of chlorine and steam through the system?

**38. Hydrochloric Acid.**—(a) *Preparation—Solubility.*—Put  $\frac{1}{2}$  gram of salt in a test-tube and add 0.5 cc. of concentrated sulfuric acid(?). Breathe across the mouth of the tube(?). Is the gas colored? Test it with litmus paper. Notice the odor *with care not to breathe deeply*. Put the thumb over the mouth of the tube and invert it quickly with the mouth under the surface of the water in a dish or sink, removing the thumb immediately(?).

(b) *Action on Metals.*—Put a piece of zinc in one test-tube and some iron filings in another. Add dilute hydrochloric acid to each and demonstrate what gas is evolved. Write the equations.

(c) *Action on Hydroxides—Indicators.*—Fill two small beakers half full with water. Add to one a few drops of a litmus solution and to the other two drops of a  $\frac{1}{2}$  per cent. solution of phenol phthalein (the phenol phthalein is dissolved in alcohol and the solution diluted).

Add one drop of a solution of sodium hydroxide (10 percent.) to the contents of each beaker and notice the color. Add a few drops of hydrochloric acid to each beaker, stirring the solutions with a glass rod, then add again a solution of sodium hydroxide. Finally drop in either hydrochloric acid or sodium hydroxide carefully till the color change is produced by a single drop of the reagent, giving a neutral solution. Taste a drop of the solution on the end of a glass rod. Evaporate some of it to dryness in a porcelain dish and examine the residue(?).

(d) *Action on Oxides.*—Put a little (0.25 gram) zinc oxide in a test-tube and add a little water. Does it dissolve? Add dilute hydrochloric acid and shake(?).

Repeat with a little lime. Evaporate the solution obtained in a porcelain dish till the residue is solid and then expose some of the residue to the air for some time(?).

Put a few milligrams of very finely powdered ferric oxide,  $\text{Fe}_2\text{O}_3$ , in a test-tube, add 2 to 3 cc. of concentrated hydrochloric acid and warm gently, just short of boiling till the oxide





dissolves. Compare the solution with the solution obtained by dissolving iron in hydrochloric acid. Write the equation.

(e) *Action on Oxidizing Agents.*—Put 0.25 gram or less of potassium dichromate,  $K_2Cr_2O_7$ , in a test-tube, add 1 cc. of concentrated hydrochloric acid, warm and demonstrate the nature of the gas evolved. Dilute the solution and notice the color. Write the equation.

Summarize the action of hydrochloric acid.

**39. Potassium Hypochlorite.**—Dissolve 5 grams of potassium hydroxide in 15 cc. of water.

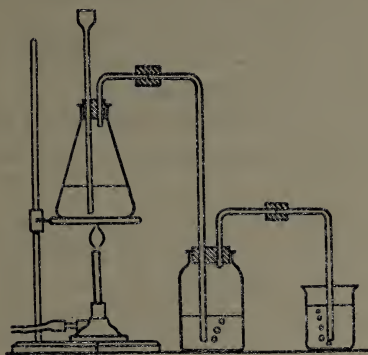


FIG. 26.

Calculate how much potassium permanganate and how much hydrochloric acid of 40 per cent. will be required to furnish enough chlorine to saturate the 5 grams of potassium hydroxide.

Arrange a 100-cc. flask, A, with a thistle tube and delivery tube connected to a 100-cc. wash bottle, B, containing 10 cc. of water. The tube by which the chlorine enters the wash-bottle should reach to the bottom of the bottle. Put one-fourth more than the calculated amount of potassium permanganate in the generating flask and add in small portions one-half more than the calculated amount of concentrated hydrochloric acid. Enough of the acid must be added at the start so that the lower end of the thistle tube is covered, but this should be close to the bottom of the generating flask.

Dilute 5 cc. of the potassium hydroxide solution to 20 cc., putting this in a test-tube. Put the remainder of the concentrated solution of potassium hydroxide in a small beaker and pass the washed chlorine into this till it is saturated. The solution should become quite warm in this process and should remain colorless till the chlorine is in excess. What effect has this and the fact that the solution becomes acid at the close upon the transformation desired? Set the solution aside to crystallize and use it for 41.

After saturating the concentrated solution of potassium hydroxide with chlorine pass chlorine into the dilute solution of potassium hydroxide but do not pass an excess into this solution(?). The last portion of the chlorine may be obtained by gently warming the generating flask.

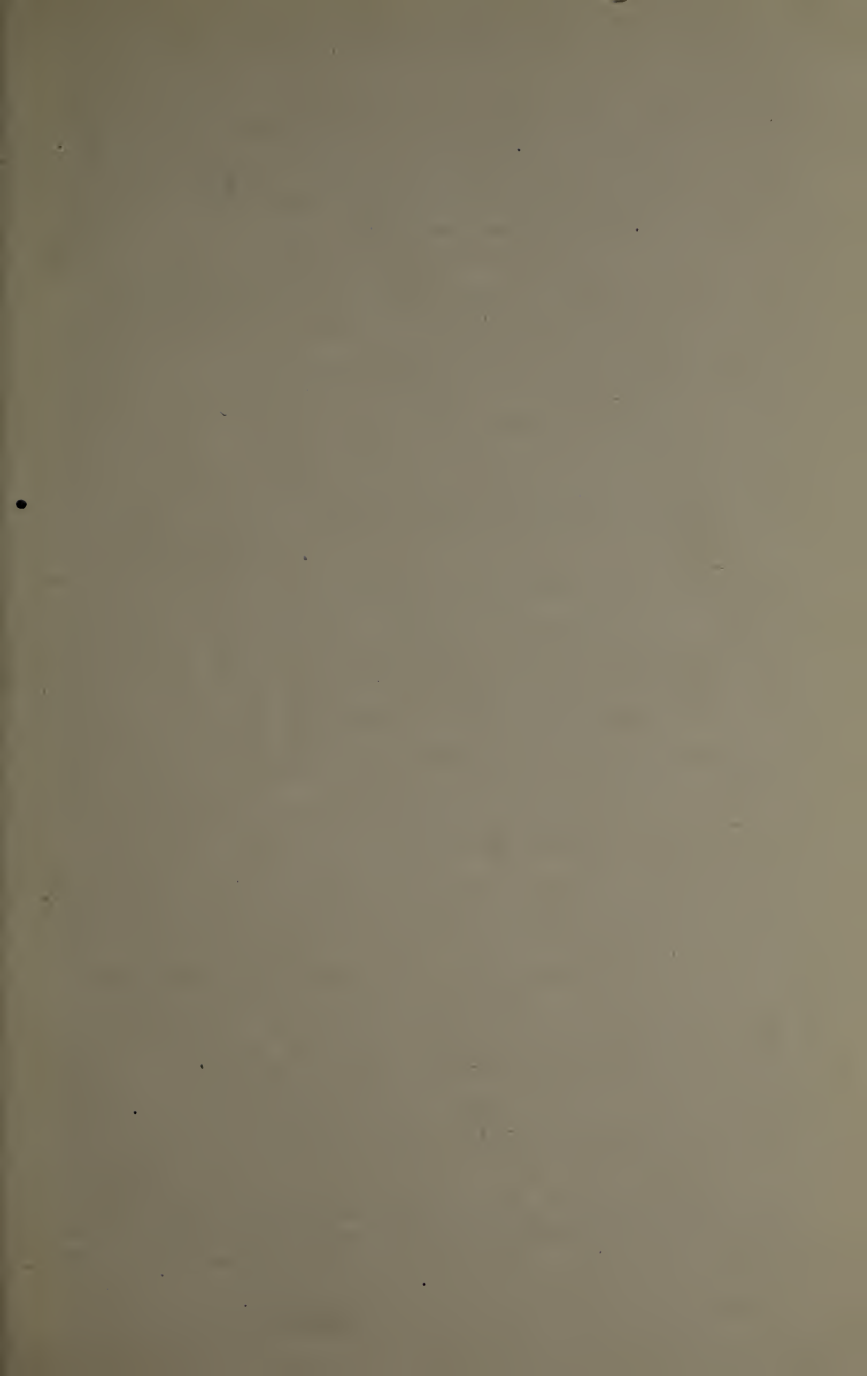
Acidify a part of the solution with dilute sulfuric acid and test the solution with litmus paper(?), also with some colored calico.

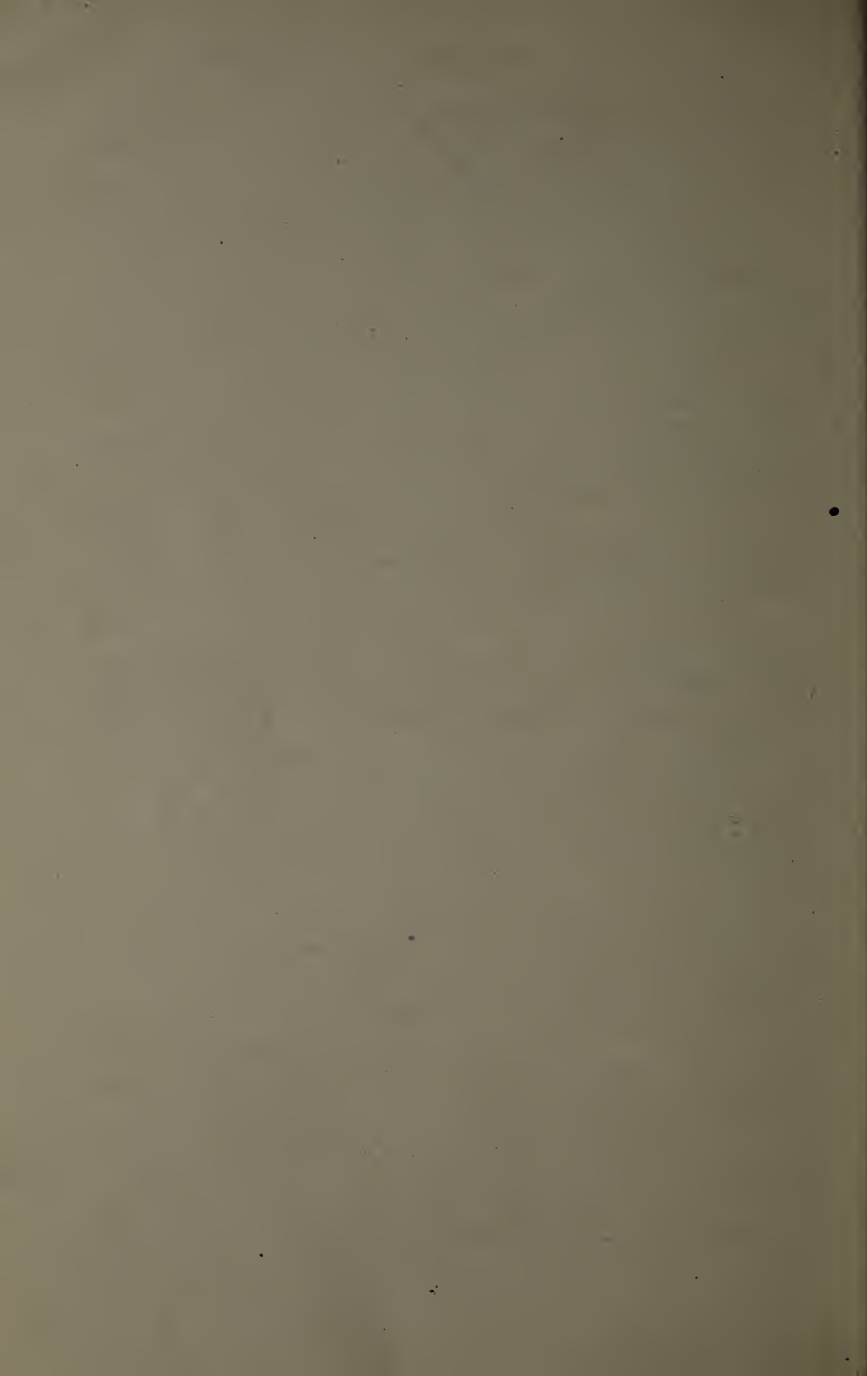
**40. Bleaching Powder.**—Put  $\frac{1}{4}$  gram of potassium permanganate in a 20-cm. test-tube and add concentrated hydrochloric acid drop by drop till the tube is two-thirds filled with chlorine as seen by the color. Put  $\frac{1}{4}$  gram of slaked lime,  $\text{Ca}(\text{OH})_2$ , in a second 20-cm. tube and pour the chlorine gas from the first tube into this with care not to pour out any of the solution of manganous chloride. Notice the absorption of the chlorine by the calcium hydroxide. What is formed? Add 1 to 2 cc. of dilute sulfuric acid and notice whether the chlorine is again liberated.\* Write all of the equations.

Mix some bleaching powder (1 gram) with water. Dip a piece of colored calico in the solution and then in some water to which a little sulfuric acid has been added. If necessary, dip in the hypochlorite solution and then in the acid a second and third time. Write the equations. Add 1 cc. of hydrogen peroxide to 1 cc. of the hypochlorite solution(?).

**41. Potassium Chlorate.**—Pour off the mother liquors from the white crystals which separate from the concentrated solution of potassium hydroxide which has been saturated with chlorine in 39, and allowed to stand. Rinse the







crystals with a *very little* water twice. Dry them and determine their character by appropriate experiments. Does an acidified dilute solution of these crystals change color as a solution of a hypochlorite does? Does such a solution bleach litmus paper? What are the relative stabilities of hypochlorites and chlorates?

**42. Potassium Perchlorate.**—Put 5 grams of potassium chlorate in a 20-cm. test-tube and heat it till it melts. Keep it just above the melting point at such a temperature that there is a very slow evolution of oxygen. Continue to heat till the mass becomes nearly or quite solid because of the transformation of a considerable part of the potassium chlorate into a mixture of potassium perchlorate and potassium chloride. Write the equation, also the equation that gives oxygen from potassium chlorate.

Allow the tube to cool till it can be held in the hand. By inverting it and tapping it gently on the table the solid can usually be loosened from the tube. Put the solid in a beaker with 20 cc. of water, heat to boiling and pour off the clear solution into another beaker leaving any undissolved salt in the first beaker. Boil the residue with a fresh portion of water and pour off into the same beaker, repeating till all of the salt has been brought into solution.

Let the solution cool thoroughly, pour off the mother liquors as completely as possible, add 2 to 3 cc. (not more) of water to the crystals of potassium perchlorate, decant the wash water and repeat three or four times. Then transfer the crystals to a filter paper and allow them to dry in the air.

Put a few drops of concentrated sulfuric acid in each of two *dry*<sup>1</sup> test-tubes. To one add a *very small* amount of potassium chlorate, to the other a similar amount of potassium perchlorate(?). *Handle with care*(?). Rinse out the tubes at once after the tests have been made. Write equations for the two reactions.

<sup>1</sup>At the close of each exercise test-tubes which have been used should be rinsed out and left *inverted* in the test-tube rack so that clean, *dry* tubes may always be available.

**43. Ionization.**—Connect one pole of a storage battery or dry cell with an ammeter and connect copper wires to the other pole of the battery and to the other binding post of the ammeter. Dip the wires successively in the following solutions and note which of these are conductors. Rinse the wires each time before placing them in a fresh solution.

- (a) Distilled water.
- (b) Dilute hydrochloric acid.
- (c) A sugar solution.
- (d) A solution of salt.
- (e) A solution containing alcohol.
- (f) A solution of sodium hydroxide.
- (g) A solution of ammonia.

The solutions may be dilute and should be placed in a beaker, or U-tube. In the former case care must be taken not to touch the wires together. If platinum wires are used, gases will be liberated in some cases (?). With copper wires a gas is usually liberated from only one pole(?).

**44. Hydrolysis.**—Take 1 cc. of a solution of antimony trichloride,  $\text{SbCl}_3$ , in a test-tube and add some water. The precipitate is antimony oxychloride,  $\text{SbOCl}$ . Write the equation. See if the reaction is reversible. Antimony is partly metallic and partly nonmetallic. What would you expect if the hydrolysis were complete?

**45. Law of Multiple Proportions.**—Repeat experiment 19(a) or (b), using potassium perchlorate in place of potassium chlorate. The collection and measurement of the oxygen serves as a check on the results but is not essential for our present purpose. Calculate the per cent. of oxygen found in potassium perchlorate. Deduce from the results, combined with the results previously obtained with potassium chlorate, (19) a demonstration of the law of multiple proportions:

(a) On the basis that a fixed amount of potassium chloride is combined with different amounts of oxygen.

(b) On the basis that a fixed amount of oxygen is combined with different amounts of potassium chloride.





## CHAPTER VIII

## THE HALOGEN FAMILY

**46. Bromine.**—(a) *Preparation.*—Dissolve a few milligrams of potassium bromide in water in a test-tube. Add 1 cc. of chlorine water. Notice the color of the solution and also the odor(?).

Put 5 to 10 mg. (not more) of potassium bromide in a test-tube, add an equal amount of manganese dioxide and then a few drops of concentrated sulfuric acid(?). Warm very gently, if necessary. Pour the vapor into a second tube containing two or three drops of a solution of potassium iodide(?).

(b) *Hydrobromic Acid.*—Put 0.5 gram of potassium bromide in a test-tube and add 0.5 cc. of concentrated sulfuric acid. Breathe across the tube. Compare with the conduct of hydrochlorid acid in 38. Why is the gas colored? Write the equations.

(c) *Sodium Hypobromite.*—Take 2 cc. of bromine water in a test-tube and add a solution of sodium hydroxide drop by drop till the solution becomes colorless(?). Add a few drops of dilute sulfuric acid. Write the equations and compare with the action of chlorine on potassium hydroxide.

(d) *Sodium Bromate.*—Repeat (c) but after adding the sodium hydroxide boil the solution for a few minutes and cool it before adding the sulfuric acid. Compare with the conduct of hypochlorous and chloric acids. Which is more stable, a solution of hypobromous or of bromic acid?

**47. Iodine.**—(a) *Preparation.*—One method of preparation has been illustrated under (a) above. The effect of sulfuric acid on a few milligrams of a mixture of potassium iodide and manganese dioxide may also be tried.

(b) *Reaction with Starch.*—Take a few milligrams of starch in a test-tube and boil it with 10 cc. of water. Put a few milligrams of potassium iodide in another test-tube, dissolve this in water, add a few drops of chlorine water(?) and then a



little of the starch paste(?). Notice that the color will disappear on heating the solution and reappear on cooling it.

(c) *Solubility*.—Put a few milligrams of iodine in each of three test-tubes. Add water to the first, 1 cc. of alcohol to the second and 1 cc. of a solution of potassium iodide to the third. What is the pharmaceutical name of the solution in alcohol? What does the solution in potassium iodide contain?

(d) *Reducing Action of Hydriodic Acid*.—Put a few milligrams of potassium iodide in a dry test-tube, add a drop of concentrated sulfuric acid and warm gently. The odor may be noted, carefully(?).

**48. Hydrofluoric Acid.**—Cover a piece of glass 4 cm. square with a thin coating of wax or paraffin by warming it gently and rubbing a piece of the material over the surface. With a pointed piece of wood draw some figures or letters in the wax, exposing the surface of the glass. Put 5 grams of calcium fluoride in a shallow lead dish about 3 cm. in diameter, or a porcelain dish which has been *completely* coated with paraffin may be used. Add 2 or 3 cc. of concentrated sulfuric acid and mix this with the fluorspar with a match stick. Avoid breathing the acid fumes, as they are very *poisonous*. Lay the glass which has been prepared on the dish, with the wax surface downwards and set it away in the hood till the next exercise. On the following day warm the glass in the flame and remove the wax by rubbing it with filter paper. Write the equation for the reaction between hydrofluoric acid and calcium silicate,  $\text{CaSiO}_3$ .

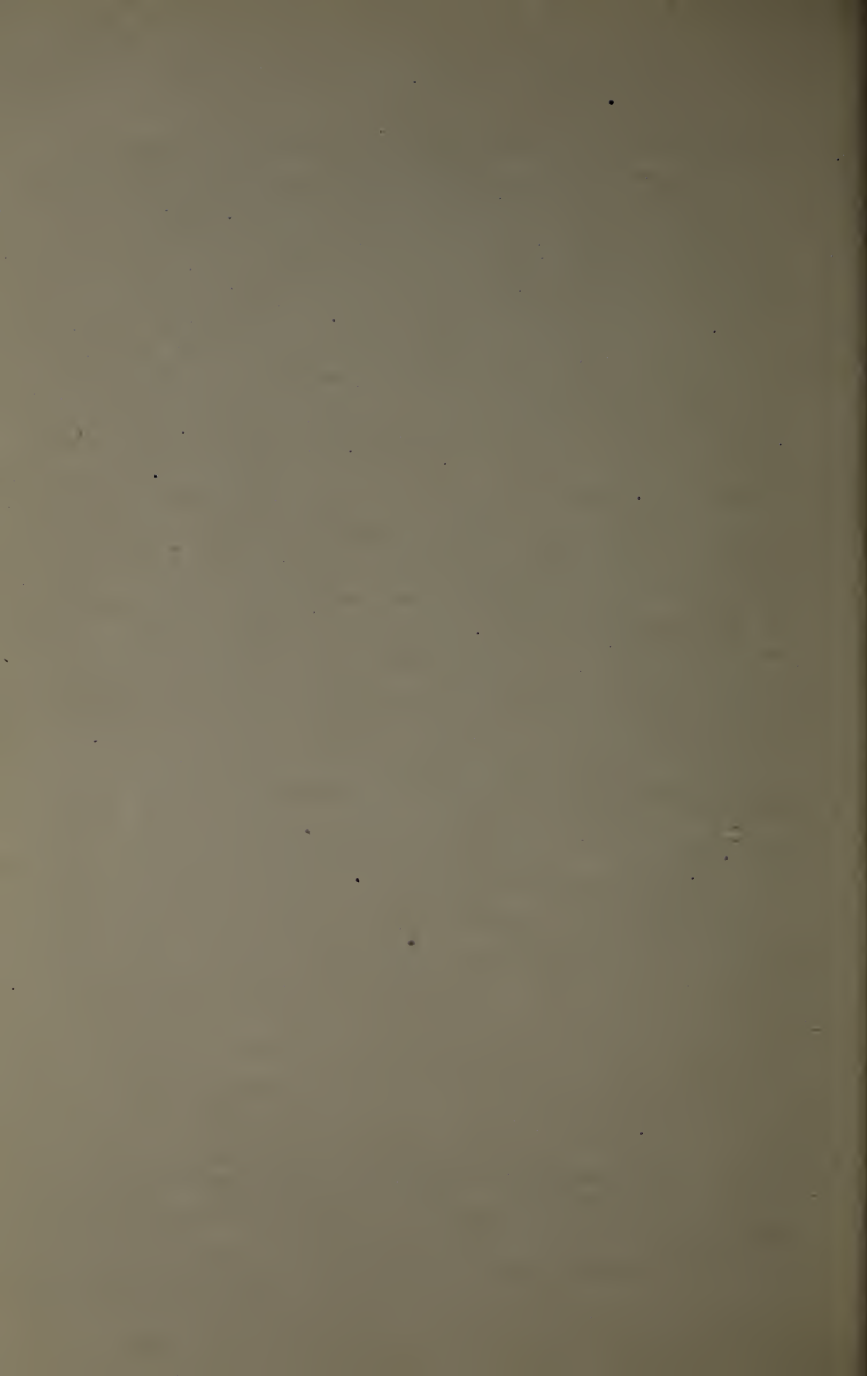
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## CHAPTER IX

### SULFUR

**49. Allotropic Forms of Sulfur.**—(a) *Rhombic Sulfur*.—Dissolve  $\frac{1}{2}$  gram of sulfur in 2 or 3 cc. of carbon disulfide, pour the solution into a watch-glass *in the hood* or out of doors and allow the solution to evaporate and crystallize. Notice the





character of the crystals. *Carbon disulfide is very volatile and inflammable and the neighborhood of flames must be avoided.*

(b) *Monoclinic Sulfur*.—Melt 10 grams of sulfur in a wide test-tube taking care to avoid overheating. Allow the tube to stand quietly till the liquid has partly solidified, then pour off the liquid portion. Examine the crystals, noting especially their shape, color and translucency. Allow some of them to remain till the following day and notice the change.

(c) *Amorphous Sulfur*.—Heat the sulfur in the same tube *slowly* to a temperature considerably above its boiling point and notice the viscous stage when the tube may be inverted for a minute without the sulfur running out. Heat further till the sulfur boils and by heating the walls of the tube above the boiling liquid, to prevent condensation, observe the true color of sulfur vapor. Finally pour some of the boiling liquid into some cold water and examine the plastic form of sulfur obtained. When this has solidified on the following day examine it for crystals and treat a little of it with carbon disulfide, in a dry test-tube. Does it dissolve?

(d) *Gaseous Sulfur*.—See 50(b).

**50. Properties of Sulfur** (a) *Combination with Iron*.—Recall 14.

(b) *Combination with Copper*.—Calculate how much sulfur will be required to fill a 15-cm. test-tube with vapor at  $445^{\circ}$  on the supposition that the formula of the vapor is  $S_8$ . To determine the volume of the tube select two dry tubes of the same size and measure the volume of one by filling it with water and emptying it into a measuring cylinder. The dry tube is then used for the rest of the experiment.

Weigh a little more than the required amount of sulfur and heat all of the lower portion of the tube above the boiling point of sulfur, observing the true color of sulfur vapor. Thrust into the vapor a copper wire 1 mm. or less in diameter, holding it by the end. *Do not drop it*. Examine the product and write the equation.

(c) *Combination with Hydrogen*.—See following paragraph.

**51. Hydrogen Sulfide.**—(a) *Formation from the Elements. Reversible Reactions.*—Bend a tube 3 to 5 mm. in diameter and 30 cm. in length at right angles, in the middle. Put 0.5 gram of sulfur in one arm of the tube and keeping this arm horizontal pass a current of hydrogen by means of the tube through 10 cc. of water, containing a few drops of a solution of lead nitrate. Pass the gas slowly enough so that the bubbles can be very easily counted. After noting that the hydrogen produces no precipitate or coloration in the solution, *and after making sure that the hydrogen is free from air (24d)*, heat the tube, beginning from the side of the sulfur away from the generator so that the mixture of hydrogen and sulfur will pass the heated portion of the tube as the sulfur is volatilized(?). Is the combination of the sulfur with the hydrogen complete? If hydrogen were brought in contact with an excess of oxygen at this temperature would the combination be complete? Would it be complete at all temperatures? Answer the same questions for hydrogen with chlorine? With bromine? With iodine? To remove the sulfur from the tube and prepare it for the following experiment connect the tube with a wash bottle containing 20 cc. of water and draw air through the tube while it is heated, beginning from the side next the wash bottle. If heated properly(?) the sulfur will be completely burned to sulfur dioxide and the latter will be mostly absorbed by the water. Test the solution with litmus. What is formed? Save the solution for 51f and 52.

(b) *Dissociation.—Reversible Reactions and Equilibria. Caution!! Hydrogen sulfide is poisonous and must not be allowed to escape into the air of the laboratory. The head should never be placed in a hood where the gas is generated or delivered.* Put 50 cc. of water in a 100-cc. flask and pass hydrogen sulfide *very slowly* through the water with the tube used in the previous experiment. Heat the horizontal portion of the tube(?). After noting the result, continue to pass a slow current of hydrogen sulfide into the water for several minutes, at the same time shaking the flask to promote the absorption of







the gas. If two sealed tubes, one containing hydrogen sulfide and the other containing hydrogen with exactly the equivalent amount of solid sulfur were heated to  $500^{\circ}$  for some time, how would the contents of the two tubes compare?

(c) *Preparation*.—Put 0.1 gram (*not more*) of ferrous sulfide in a test-tube and add 1 cc. of dilute sulfuric acid or hydrochloric acid(?). If the odor of the gas is not familiar, notice this, *cautiously*. Apply a flame to the mouth of the tube(?).

(d) *Effect on Solutions of Metals*.—Put 1 cc. of the following solutions in six test-tubes: lead nitrate,  $\text{Pb}(\text{NO}_3)_2$ ; antimony trichloride,  $\text{SbCl}_3$ ; arsenic trichloride,  $\text{AsCl}_3$  (or  $\text{As}_2\text{O}_3$  in  $\text{HCl}$ ); zinc sulfate,  $\text{ZnSO}_4$ ; ferrous sulfate,  $\text{FeSO}_4$ ; and sodium sulfate,  $\text{Na}_2\text{SO}_4$ . Add 5 cc. of the hydrogen sulfide water prepared in (b) to the contents of each tube. Record the results and write the equations. If a precipitate fails to form in any tube add a few drops of ammonia(?). Add some dilute hydrochloric acid to the contents of each tube(?). Into what three groups might the metals be separated by the reagents used and how? Write a definition for each group and name the metals used which belong to it.

(e) *Separation of Antimony and Iron*.—Mix 1 cc. of a solution of antimony chloride with 1 cc. of a solution of ferrous chloride, dilute, adding some hydrochloric acid if necessary to retain the antimony in solution (see 44). Separate the antimony and iron by the principles illustrated in (d).

(f) *Reducing Action*.—To 1 cc. or less of a solution of potassium dichromate add some hydrochloric acid and then enough of the hydrogen sulfide solution to cause the solution to turn green and milky(?). Write the equation. Chromium is sexivalent in potassium dichromate and trivalent in chromic chloride,  $\text{CrCl}_3$ . How many molecules of hydrogen sulfide will one atom of chromium oxidize?

Put 1 cc. of a solution of ferric chloride in a test-tube, add some hydrogen sulfide water and warm gently(?).

Mix some of the solution of sulfur dioxide from 51(a) with some of the solution of hydrogen sulfide(?).

**52. Sulfur Dioxide.**—(a) *Preparation.*—Put  $\frac{1}{2}$  gram of copper turnings in a test-tube, add 2 cc. of concentrated sulfuric acid(?), insert a stopper with a delivery tube, warm (*care*) and collect three or four 20-cm. tubes full of the gas by conducting it into the tubes, held upright, till the odor of the sulfur dioxide is apparent at the mouth of each tube. Stopper the tubes and use the gas for the experiments given below.

(b) *Bleaching.*—Put in one of the tubes a piece of colored calico which has been thoroughly moistened and squeezed as dry as possible. Stopper the tube and allow it to stand for some time. Afterwards expose the calico to sunlight for a half hour and notice the effect. How does the bleaching action differ from that of chlorine?

(c) *Solubility.*—Put 3 cc. of water into one of the tubes containing sulfur dioxide and shake vigorously. Test the solution with litmus paper but notice that the odor of sulfur dioxide is still very marked, showing that the solution gives off the gas easily to the air.

(d) *Acid Properties of the Solution.*—Add a few milligrams of calcium carbonate to the solution containing sulfurous acid. Notice that it dissolves and that a gas(?) is evolved. Add a little more of the carbonate, put the thumb over the end of the tube and shake vigorously. Notice that the odor of sulfur dioxide has now disappeared. Pour the gas in the tube carefully into another tube containing 1 cc. of lime water(?) Filter and divide the solution of calcium sulfite into two portions. Add dilute hydrochloric acid to one, dilute sulfuric acid to the other(?).

Moisten a strip of filter paper with the solution and dry it on a piece of glass or watch glass on a water bath or the steam radiator. Compare with 53(c).

(e) *Reducing Action. Oxidation to Sulfuric Acid.*—Take 5 cc. of the solution of sulfur dioxide from 51(a) in each of three test-tubes. Add one or two drops of a dilute solution of po-





tassium dichromate to the first(?) and a few drops of a dilute solution of potassium permanganate to the second(?). Now add a few drops of barium chloride,  $\text{Ba Cl}_2$ , to each of the three tubes(?).

**53. Sulfuric Acid.**—(a) *Preparation.*—Burn a small fragment of sulfur, held in a deflagrating spoon, in each of two dry, wide-mouthed bottles. Put 10 cc. of water in one of the bottles, shake and add a few drops of a solution of barium chloride to the solution of sulfurous acid obtained(?).

Put two or three drops of red fuming nitric acid (*care*) in the other bottle. Pour the gases and vapors into another bottle and back again (?). After a short time add 10 cc. of water, shake, and test the solution with barium chloride as before(?).

Explain how a sulfite may be distinguished from a sulfate.

(b) *Dilution.*—Put 1 cc. of water in a test-tube and add 1 cc. of concentrated sulfuric acid(?). Why is it dangerous to pour water on concentrated sulfuric acid?

(c) *Effect on Organic Matter.*—Moisten a filter paper with a drop of dilute sulfuric acid and dry the paper on the water bath or steam radiator.

Put 1 gram of sugar in a small beaker, moisten with a few drops of water and add 1 cc. of concentrated sulfuric acid(?).

(d) *Action of Concentrated Sulfuric Acid on Metals.*—Put 0.5 gram of iron filings in a dry test-tube and add 2 cc. of concentrated sulfuric acid. If no action takes place in the cold, warm the mixture(?). Compare with 52(a) and with 23(c).

(e) *Action on Salts.*—Recall the action of sulfuric acid on sodium chloride, potassium bromide, potassium iodide and calcium fluoride. What is the action on potassium nitrate?

**54. Sodium Thiosulfate.**—Take 5 cc. of a solution of sodium hydroxide (10 per cent.) and pass sulfur dioxide into it till the solution smells of the gas(?). Add 5 cc. more of the solution of sodium hydroxide and mix(?).

Take one-half of the solution just prepared, add 0.5 gram of powdered sulfur, boil for a short time and filter(?).

Test a little of the last solution with dilute hydrochloric acid(?).

Take 1 cc. of a solution of silver nitrate, add 1 cc. of a solution of salt and shake vigorously till the precipitate(?) settles easily. Pour off the liquid, add water and decant this several times to wash the precipitate. Divide the precipitate into two portions. To one add some of the solution of sodium sulfite; to the other some of the solution of sodium thiosulfate(?). What is the application of the properties illustrated in photography?

**55. Normal Solutions.**—Dilute 130 cc. of sodium hydroxide (10 per cent.) to 300 cc. The solution should now be somewhat more concentrated than a “normal” solution(?).

Weigh a 30-cc. porcelain dish, accurately. Measure 10 cc. of the solution into the dish, accurately, with a pipette. For this purpose the pipette is filled above the mark by sucking the liquid into it, taking care not to draw any into the mouth. The moistened finger is placed over the top end of the pipette and by raising the finger carefully the liquid is allowed to run out till the bottom of the meniscus is *exactly* at the mark. Any liquid on the outside of the tip of the pipette is removed by touching it to a moist surface. The liquid in the pipette is then delivered into the porcelain dish with the tip of the pipette in contact with the moist surface. The pipette is to be held in a vertical position and removed as soon as the delivery is complete.<sup>1</sup> Add 1.2 cc. of concentrated hydrochloric acid or 5 cc. of the dilute acid (1:4). Evaporate the solution on a water bath and dry it for  $\frac{1}{2}$  hour after it *appears dry*. Cover the dish with a watchglass and heat for a short time on a wire gauze, heating very carefully at first to avoid decrepitation of the salt. Allow the covered dish to cool and weigh it again. From the weight of the salt obtained, calculate the weight of the sodium hydroxide

<sup>1</sup> Directions of the U. S. Bureau of Standards.







in 1 cc. of the solution. Why is it not necessary to measure the hydrochloric acid accurately, provided an excess is used?

Calculate the weight of sodium hydroxide in 250 cc. of the solution and then the number of cubic centimeters of a normal solution which this weight of sodium hydroxide would give. Measure 250 cc. of the solution in a measuring cylinder and make the volume up to the volume calculated. Mix thoroughly by pouring from the cylinder into a dry flask or bottle and back into the cylinder several times and use the solution for the following experiment.

On the supposition that 1 cc. of the dilute sulfuric acid of the laboratory contains 0.25 gram of sulfuric acid, calculate how many cubic centimeters will be required to give 100 cc. of normal sulfuric acid. Measure this volume of the acid from a burette into a 100-cc. measuring cylinder, fill the cylinder to the mark, and mix by pouring back and forth into a dry flask. Measure 10 cc. of the normal sulfuric acid into a 100 cc. flask with a pipette and dilute to 50 cc. Add two or three drops of a solution of methyl orange or methyl red, and then run in the normal sodium hydroxide from a burette, till the end point is exactly reached. From the volume of the sodium hydroxide solution used calculate the normality factor of the sulfuric acid, *i.e.*, how many cubic centimeters of truly normal sulfuric acid 1 cc. of the acid prepared is equivalent to.

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## CHAPTER X

### NITROGEN—AIR

**56. Ammonia.**—(a) *Preparation from Ammonium Chloride.*—Put  $\frac{1}{4}$  gram of ammonium chloride in a test-tube and add 2 cc. of a solution of sodium hydroxide. Notice the odor and test the gas, after warming, with moist litmus paper(?) and also with a rod moistened with concentrated hydrochloric acid(2(d))(?).

(b) *Preparation from Aqua Ammonia.*—Fit a 20-cm. test-tube with a cork bearing a straight delivery tube 20 cm. in length. Put 5 cc. of concentrated aqua ammonia (sp. gr. 0.90) in the test-tube, insert the stopper with the delivery tube and by boiling gently fill two 20-cm. test-tubes, inverted over the delivery tube, with ammonia gas. Boil the solution only long enough to fill the tubes. How can you tell when they are full? Stand the tubes on the desk with the mouths downward. Why?

(c) *Solubility.*—Immerse the mouth of one of the tubes in a small beaker filled with distilled water(?). Test the solution with litmus paper (?).

(d) *Combination with Acids.*—Put 0.25 gram (not more) of salt in a 20-cm. test-tube and add a few drops of concentrated sulfuric acid, just enough so that the hydrochloric acid evolved is apparent at the mouth of the tube. Bring the second tube filled with ammonia over the tube filled with hydrochloric acid(?). The solid formed may be tasted cautiously. What substance does the taste recall? Is there any connection between the formulas of the two compounds?

Write the formulas of the compounds of ammonia with eight acids and give the name of each.

**57. Nitric Acid.**—(a) *Preparation.*—*Oxidizing Power.*—Put 1 gram of potassium nitrate in a test-tube and add 1 cc. of concentrated sulfuric acid(?). Put a small plug of woolen yarn in the mouth of the tube and heat the tube till the nitric acid expelled comes in contact with the yarn. The tube should be held with a test-tube holder, not with the fingers.

What is the difference in conduct when sulfuric acid is added to saltpeter and when it is added to salt? Why?

(b) *Action on Copper.*—*Preparation of Nitric Oxide.*—Put 1 gram of copper turnings in a 20-cm. test-tube which is fitted with a stopper and bent delivery tube. Add 3 cc. of nitric acid (sp. gr. 1.20) and collect over water one large test-tube full and a second test-tube one-third full of the gas evolved (?). Why is the gas in the generating tube colored at first





and why does it become nearly or quite colorless later? What is the relation between the following: The action of nitric acid on copper? Of concentrated sulfuric acid on iron? Of dilute sulfuric acid on iron?

(c) *Properties of Nitric Oxide*.—Raise the tube filled one-third full of nitric oxide so that a little air will enter it. Notice and explain the following: (1) The formation of a colored gas. (2) The sudden increase in volume when the nitric oxide and air mix. (3) The disappearance of the color as the gas remains in contact with the water or is shaken with it. The admission of air and formation of a colored gas may usually be repeated once or twice.

What is the connection between this experiment and the commercial manufacture of nitric acid from the air?

Thrust a splinter with a live coal on the end into the other test-tube filled with nitric oxide(?). Compare with the action of nitrous oxide on a glowing splinter. What weight of oxygen does 1 liter of nitric oxide contain? One liter of nitrous oxide? One liter of oxygen weighs 1.429 grams and the calculation is very easy if the right principle is used.

Does nitric oxide support the combustion of any substances?

(d) *Action of Dilute Nitric Acid on Iron*.—Put 1 gram of iron turnings in a test-tube. Add 5 cc. of water and 1 cc. of dilute sulfuric acid(?), then add a few drops of dilute nitric acid at a time till about  $1/2$  cc. has been added, cooling if the action is too vigorous. After a few minutes pour the contents of the tube into a small beaker and add 4 or 5 cc. of a solution of sodium hydroxide. If the odor of ammonia is not apparent, cover the beaker with a watch-glass, on the lower side of which is placed a moistened piece of red litmus(?).

Write the equations for the following reactions: iron and sulfuric acid; hydrogen and nitric acid, giving ammonia; ammonia and sulfuric acid; ferrous sulfate and sodium hydroxide, giving ferrous hydroxide,  $\text{Fe}(\text{OH})_2$ ; ammonium sulfate and sodium hydroxide.

Write equations for the series of reactions in which nitric acid is reduced by hydrogen, giving five different products.

**58. Nitrous Oxide.**—Put 4 grams of ammonium nitrate in a 50-cc. flask. Fit a stopper and delivery tube to conduct the gas to the bottom of a 500-cc. bottle.

Heat the ammonium nitrate till it melts and continue to heat gently so that the nitrate decomposes slowly. If heated too rapidly the salt may decompose explosively. Continue to generate the gas till the bottle is filled as shown by a glowing splinter applied at its mouth. Put a few milligrams of red phosphorus in a deflagrating spoon, ignite this with a hot file or glass rod and insert it at once into the nitrous oxide(?)

What is the commercial use of nitrous oxide?

**59. Nitric Oxide.**—See 57(b) and (c).

**60. Sodium Nitrite and Nitrous Anhydride.**—Put 1 gram of sodium nitrate in an iron crucible 3 or 4 cm. in diameter, supported on a triangle. Heat with a burner till melted, add 1 gram of powdered copper, stir with a file or glass rod and allow to cool. Dissolve the salt in a small amount of water and pour the solution into a test-tube. Dissolve some sodium nitrate in water in another test-tube. Add dilute sulfuric acid to the contents of each tube and note the difference. Explain and write the equation.

What three gases does the vapor obtained by evaporating liquid nitrous anhydride contain? What is obtained by absorbing these gases in cold water? In warm water?

**60. Nitrogen Dioxide and Nitrogen Tetroxide.**—Pass the mixture of oxides of nitrogen obtained by warming 5 grams of arsenious oxide,  $As_2O_3$ , with 10 cc. of nitric acid, of sp. gr. 1.32, through a calcium chloride tube into a 50-cc. flask surrounded with a mixture of salt and powdered ice or snow. After collecting 1 or 2 cc. of the dark green liquid(?) which condenses, pass oxygen into this until the liquid becomes nearly colorless(?). The liquid nitrogen tetroxide may be transferred to a cold tube with not too thin walls(?) and the latter drawn out and sealed.







**61. Effect of Respiration on the Air.**—Fill a 500-cc. bottle with water and invert it in the sink or a dish partly filled with water. Hold air in the lungs as long as this can be conveniently done and with a glass or rubber tube expel the air from the lungs into the bottle. Test the air in the bottle with a candle or flaming splinter(?). Is the oxygen completely removed from the air by this process? Does the air in the bottle contain anything besides nitrogen, water vapor, and oxygen? Test for one constituent with lime water(?).

**62. Determination of the Per Cent. of Oxygen in the Air.**—Arrange a 50-cc. eudiometer in the manner shown in the figure, with 30 to 40 cc. of air in the tube above the water. Bring the water without and within the tubes to the same level. Read the volume of the air carefully. Read also the temperature with a thermometer. The temperature of the air and water should be nearly the same. Read the barometer and find the aqueous vapor pressure corresponding to the temperature, from the table. Calculate the corrected volume of the air in the tube. Raise the piece of phosphorus on the wire into the air in the tube and allow it to remain for 24 hours. Lower the phosphorus. Read the volume of gas remaining in the tube, the temperature and barometer and find the aqueous vapor pressure as before. Calculate the corrected volume and then the per cent. of oxygen by volume in the air. Why is it necessary to take the pressure of the aqueous vapor into consideration? What is the composition of the gas left in the eudiometer? Where is the oxygen at the end of the experiment?

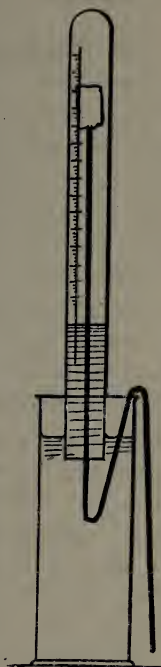


FIG. 27.

## CHAPTER XI

## PHOSPHORUS, ARSENIC, ANTIMONY AND BISMUTH

**63. Phosphorus.**—(a) *Allotropic Forms.*—Prepare a glass tube about 7 cm. long and 3 or 4 mm. in internal diameter, sealed at one end. Put a few milligrams of red phosphorus in the tube and heat it till it distills and condenses further up in the tube. When cold, cut the tube with a file and show that the phosphorus will take fire with gentle friction. The phosphorus in the tube should be completely burned before it is thrown away.

(b) *Phosphine.* (*Danger! Be careful to use exactly the amounts stated.*).—Arrange a 25-cc. flask with a cork and a bent delivery tube. Put 5 cc. of a 20 per cent. solution of sodium hydroxide in the flask and add a piece of phosphorus not more than 4 mm. cube. Insert the cork with the delivery tube and warm till the gas escapes through the water in the dish(?). What is the product formed by the combustion of the gas? *Empty the sodium hydroxide and phosphorus remaining in the flask into a jar provided in the hood for the purpose. The flask should be opened in the hood to avoid phosphorus vapors in the air of the room.*

(c) *Silver Salts of the Phosphoric Acids.*—Prepare some sodium pyrophosphate by heating 0.2 gram of disodium phosphate,  $\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$ , in a porcelain crucible on a triangle till the crucible is red hot. Allow the crucible to cool in the air.

Prepare some sodium metaphosphate by heating 0.2 gram of microcosmic salt (sodium ammonium, hydrogen phosphate,  $\text{NaNH}_4\text{HPO}_4 \cdot 4\text{H}_2\text{O}$ ) in a porcelain crucible as before.

Dissolve some disodium phosphate and the pyrophosphate and metaphosphate in water and put the solutions in three test-tubes. Add a few drops of a solution of silver nitrate to





each(?). What per cent. of silver does each salt contain? How could you demonstrate this?

(d) *Solubility of Phosphates*.—Determine which of the following metals are precipitated from their solutions by a solution of disodium phosphate: Iron, lead, copper, manganese, sodium, calcium, barium.

**64. Arsenic.** (*Remember that arsenic compounds are poisonous!*)—(a) *Reduction of Arsenic Trioxide*.—Prepare a glass tube about 7 cm. long and 4 to 5 mm. in diameter, drawn out and sealed at one end. Put a few milligrams of arsenic trioxide in the point of the tube. Cut a small piece of charcoal and introduce it into the tube above the arsenic compound. Heat the charcoal as hot as possible without soften-



FIG. 28.

ing the glass and then heat the trioxide so that its vapors will pass over the charcoal. Explain the formation of the black ring above the charcoal. After cutting off the tube and removing the charcoal the arsenic may be reoxidized by holding the tube in a slanting position over the flame(?). The crystals of the trioxide may be examined under a microscope.

(b) *Arsine*.—Prepare a generator as shown in Fig. 28. The bottle may have a capacity of 100 cc. and 5 or 10 grams of zinc may be used. Put in the bottle, also,  $\frac{1}{4}$  gram of sodium bicarbonate,  $\text{NaHCO}_3$ , to furnish carbon dioxide to expel the air and prevent an explosion. The calcium chloride tube shown in the figure may be omitted for the rough qualitative experiment.



Put enough water in the bottle to cover the lower end of the thistle tube. Add dilute sulfuric acid in small portions till it is possible to light the escaping hydrogen. Then add a few drops, *not more*, of a solution of arsenic trioxide in hydrochloric acid. Notice the color of the hydrogen flame. Hold a piece of cold porcelain in the flame and notice the deposit. Also heat the tube just back of the constricted portion and note the deposit on the walls of the tube. Explain, and write the equations. Save the deposits to compare with those obtained in 65(a).

(c) *Arsenious Sulfide and Sulfarsenite*.—Put 1 cc. of a solution of arsenic trioxide in hydrochloric acid, into a test-tube, dilute and pass hydrogen sulfide through the solution till it smells of the gas after shaking(?) Add some ammonia(?). To the clear solution add a few drops of a solution of lead acetate or lead nitrate(?). Write all equations.

(d) *Colloidal Arsenious Sulfide*.—Prepare a solution of arsenious oxide by boiling some of the powdered oxide with distilled water and filtering the solution. Pass hydrogen sulfide through some of this solution, or add hydrogen sulfide water to it(?). Add a few drops of a solution of salt, NaCl, hydrochloric acid, sugar and acetic acid to different portions of the colloidal solution(?).

(e) *Conduct of Arsenic and Antimony when Heated*.—Put small fragments of arsenic and antimony on a piece of charcoal and heat successively in a blow-pipe flame. Only a minute quantity of the arsenic should be volatilized(?). Which one melts? Which sublimes? What is the difference between sublimation and boiling?

**65. Antimony**.—(a) *Stibine*.—Repeat 64(b) using antimony trichloride in place of arsenic trichloride. (Two students at adjacent desks may well prepare arsine and stibine respectively, and compare results.) How do the deposits of arsenic and antimony differ both physically and chemically?

(b) *Antimony Sulfide and Sulfantimonite*.—Put 1 cc. of an acid solution of antimony trichloride in a test-tube. Add





some water and notice the hydrolysis. Redissolve the precipitate by adding hydrochloric acid and pass hydrogen sulfide into the solution until it smells strongly of the gas. Add some ammonia till the precipitate dissolves, passing in more hydrogen sulfide, if necessary(?). Write all of the equations.

(c) *Tartar Emetic*.—Weigh 0.1 gram of antimony trioxide. Boil it with 5 cc. of water and note whether it is soluble. Calculate the amount of cream of tartar,  $\text{KHC}_4\text{H}_4\text{O}_6$  required to combine with the trioxide. Weigh this out, add it to the trioxide and water and boil again(?). Is the solution hydrolyzed by more water?

**66. Bismuth.**—(a) *Bismuth Nitrate*.—Dissolve 0.1 gram of metallic bismuth by warming it with a few drops of concentrated nitric acid(?). Add 10 cc., or more, of water to the solution(?). What is the pharmaceutical name of the compound formed? What are its uses?

(b) *Bismuth Sulfide*.—Take 1 cc. of a solution of bismuth trichloride, add some water, and hydrochloric acid if necessary to keep the bismuth in solution(?). Pass hydrogen sulfide into the solution(?). Add ammonia and pass in more hydrogen sulfide(?). How could bismuth be separated from arsenic or antimony? Carry out the separation with a solution containing two of the metals.

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## CHAPTER XII

### CARBON. HYDROCARBONS. FLAMES

**67. Carbon.**—(a) *Graphite*.—Put a few milligrams of powdered graphite in a porcelain crucible, set it in an inclined position on a triangle and heat it for some time with the full flame of a bunsen burner(?).

(b) *Charcoal*.—Put a small piece of wood in an iron crucible 2.5 to 3 cm. in diameter. Cover the crucible, support it on a

triangle and heat it for 3 minutes over the full flame of the burner(?) When the crucible is cold, open it and examine the product.

(c) *Coke*.—Repeat (b), using 2 grams of bituminous coal, and again with anthracite and with lignite. Compare the cokes produced.

(d) *Bone Black*.—Put 3 cc. of a dark syrup in a test-tube and dilute with three volumes of water. Add a little bone black, boil and filter(?).

(e) *Illuminating Gas. Coke*.—Put 5 grams of bituminous coal in a test-tube furnished with a delivery tube. Heat the coal and collect the gas evolved over water in a 200-cc. bottle. Notice the formation of tar. Set the bottle of gas upright and test its combustibility and the luminous quality of its flame by applying a lighted match or flame(?). What are the commercial uses of this process? What are the two principal methods of manufacturing coke?

**68. Flame.**—(a) *Character of the Candle Flame*.—Blow out a candle flame and at once bring a lighted match a few millimeters above the smoking wick(?).

(b) *Temperatures of the Flame*.—Hold a tooth-pick or match-stick across the center of a candle flame(?).

(c) *Blow-pipe*.—Place some litharge on a stick of charcoal and by means of a blow-pipe reduce some of it to metallic lead(?). By using the cheeks as a sort of bellows it is possible to blow continuously while breathing through the nose.

Place a small fragment of lead on the charcoal and heat it with the oxidizing flame(?).

Repeat with a fragment of zinc, noticing the color of the coating while hot and after cooling.

*Caution!! The charcoal must be put away in a bottle or other non-combustible receptacle(?).*

(d) *Kindling Temperature of Gas*.—Lower a piece of wire gauze with a fine mesh over the flame of a burner(?). Apply a lighted match to the gases which pass through the gauze(?).







**69. Hydrocarbons.**—(a) *Methane*.—Mix 2 grams of fused, anhydrous sodium acetate with 5 grams of soda lime. Place this mixture in an ignition tube, connect with a delivery tube, heat and collect the gas evolved over water. Pour some of the gas upward(?). Ignite the gas and note the character of the flame. Write equations.

(b) *Ethylene*.—Put 2 grams of alcohol and 12 grams of concentrated sulfuric acid in a 200-cc. flask. Connect with a delivery tube, heat, not too rapidly, and collect the gas evolved over water(?). Can this gas be poured through the air? Test the inflammability and compare with methane. Write equations.

Put 10 cc. of bromine water in a bottle of the gas, shake and observe the odor(?).

(c) *Acetylene*.—Put 2 grams of calcium carbide in a 100-cc. dry(?) gas generator, fitted with a thistle tube and delivery tube. Add 10 cc. of water and collect the gas over water. Burn some of the gas and compare with methane and ethylene. Which flame gives most light? Test some of the gas with bromine water(?). Dissolve 0.5 gram of cuprous chloride,  $\text{CuCl}$ , in ammonia and test some of the gas with the solution obtained. Write equations.

(d) *Benzene and Toluene*.—If some of the light oil from gas works or a coking plant is available, subject 100 cc. of it to fractional distillation(?) and separate benzene and toluene from it. What is the difference between benzene and benzine?

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## CHAPTER XIII

### OXIDES OF CARBON—CARBON BISULFIDE —CYANIDES

**70. Carbon Dioxide.**—(a) *Preparation*.—Measure the volume of a bottle containing 400 to 500 cc., calculate how much sodium bicarbonate,  $\text{NaHCO}_3$ , and how much dilute sulfuric acid (1 cc. = 0.25 gram  $\text{H}_2\text{SO}_4$ ) will be required to furnish

enough carbon dioxide to fill the bottle. Weigh roughly the amount of bicarbonate required, put it in the bottle and add the measured amount of sulfuric acid.

(b) *Density*.—Pour the gas from the bottle into a 200-cc. beaker containing a short burning candle(?). What is the weight of a gram-molecular volume of carbon dioxide? What is the weight of a gram-molecular volume of air supposing it to contain: Nitrogen, 78 per cent.; argon (molecular weight 39), 1 per cent.; oxygen, 21 per cent.? What is the density of carbon dioxide referred to air? Calculate to three significant figures.

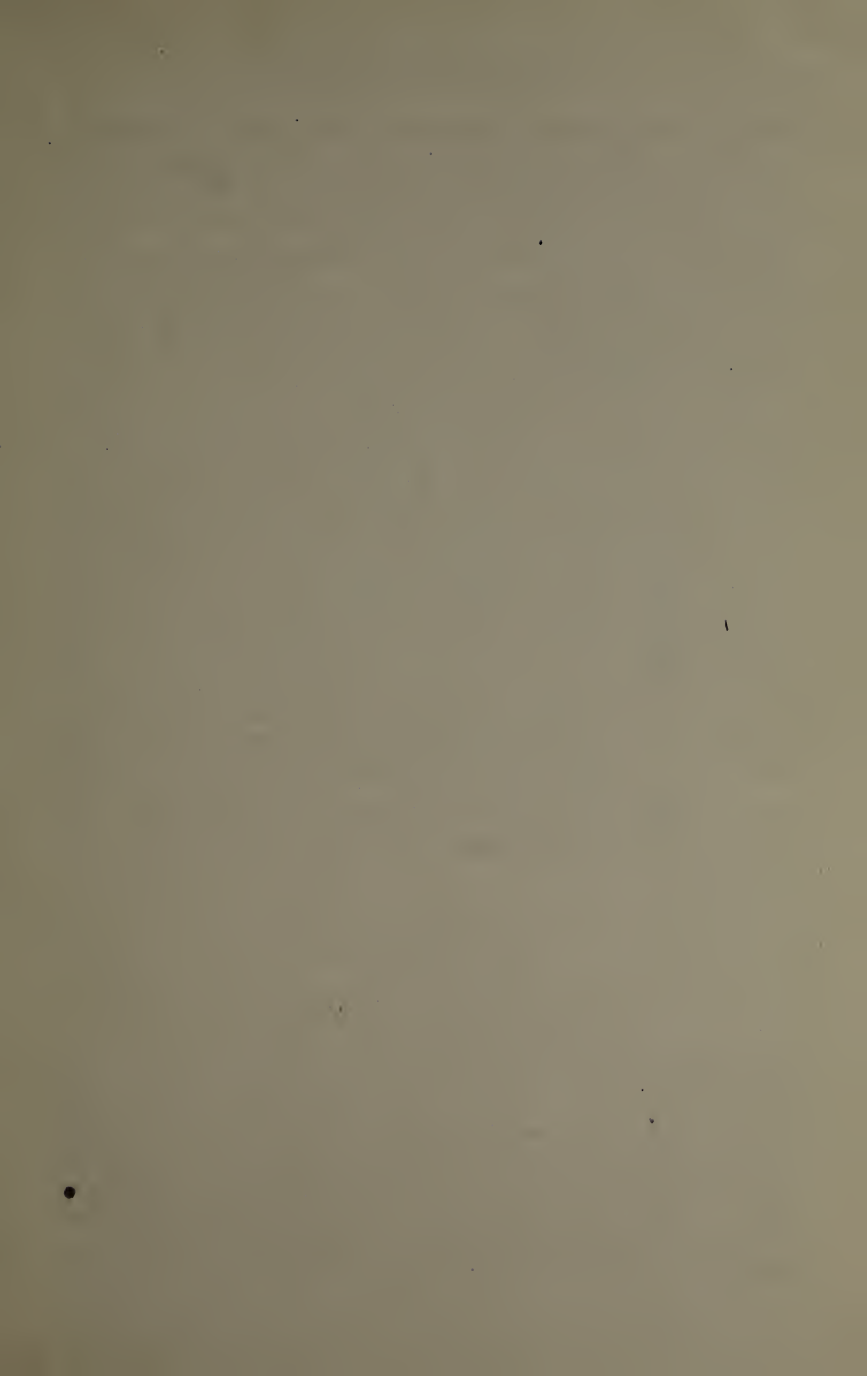
(c) *Properties as the Anhydride of an Acid*.—Fill the bottle with carbon dioxide a second time and pour it into a bottle containing 10 cc. of water colored with some blue litmus(?). Be careful not to pour out any of the liquid in the bottle in which the gas is generated. Boil the solution in a test-tube(?).

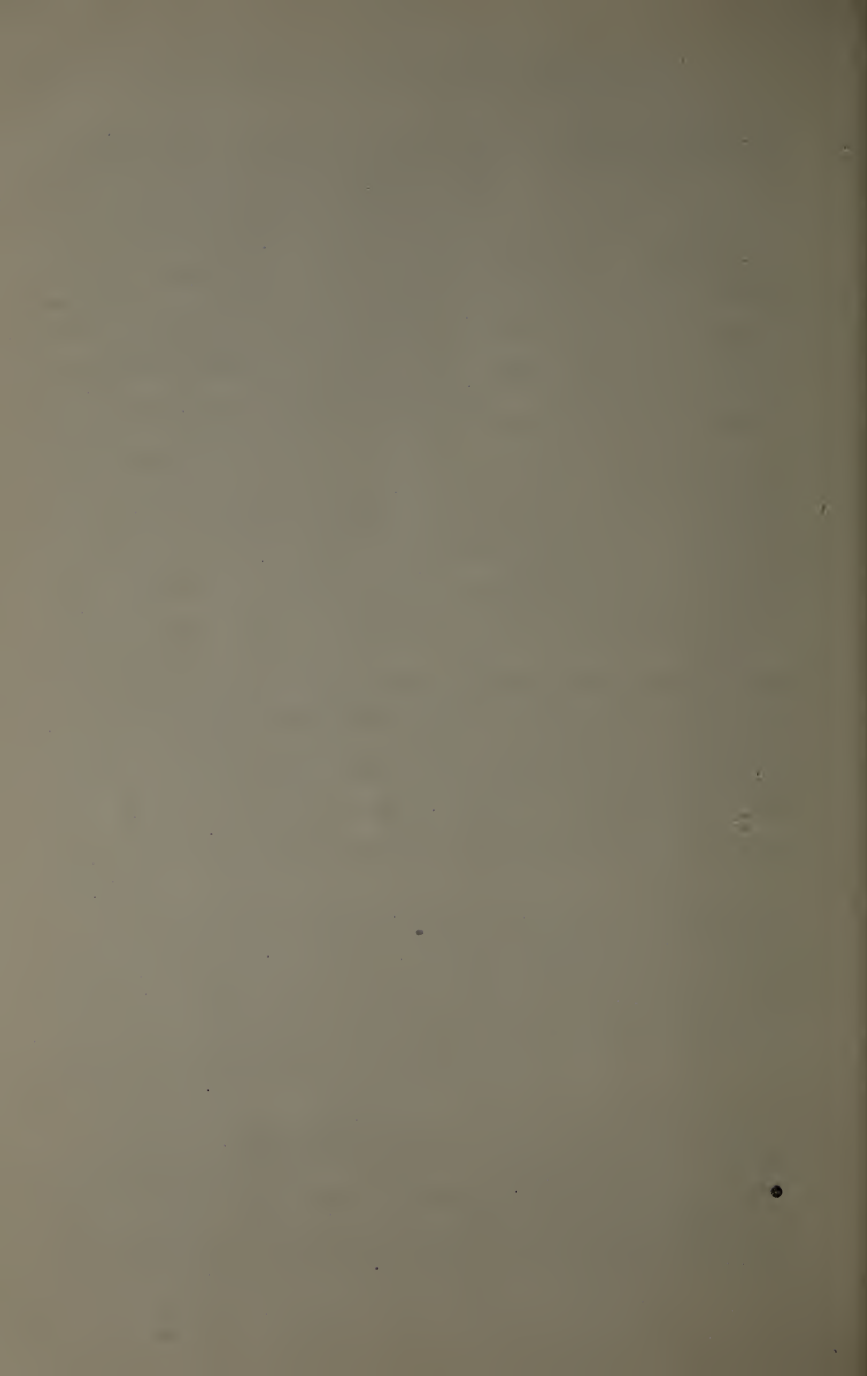
(d) *Formation of a Carbonate*.—Fill the bottle a third time and pour the gas into another bottle containing 5 cc. of a solution of sodium hydroxide. Shake the bottle to cause the absorption of the gas. Pour the solution into a test-tube and add 1 cc. of dilute sulfuric acid(?). Compare with the action of dilute sulfuric acid on the original solution of sodium hydroxide.

(e) *Formation of a Bicarbonate*.—Take 5 cc. of clear lime water in a test-tube, add 5 cc. of water and pass carbon dioxide through the solution till the turbidity, which appears at first, disappears. Boil the solution. Explain the behavior and the connection between this experiment and the formation of scale in tea kettles and in steam boilers.

(f) *Respiration*.—Recall 61.

**71. Carbon Monoxide**.—Fit a 12-cm. test-tube with a stopper and short delivery tube as shown in Fig. 29. Put  $\frac{1}{2}$  gram of oxalic acid in the tube and add 3 cc. of concentrated sulfuric acid. Put a plug of cotton in the tube, pushing it down about 6 cm. from the mouth. Put a layer of about 2 cm.





of soda lime on the cotton and insert the stopper and delivery tube. Heat the mixture of sulfuric and oxalic acids gently and burn the carbon monoxide as it escapes(?). What is the purpose of the concentrated sulfuric acid? Of the soda lime?

**72. Carbon Disulfide.**—Pour a few drops of carbon disulfide into a watch-glass. Warm a glass rod gently and bring it down slowly toward the liquid(?). Smother the flame with a towel and bring the heated rod up to the edge of the watch-glass from below(?). What is the density of the vapor of carbon disulfide as compared with air?

**73. Potassium Ferrocyanide.**—Mix some potassium carbonate with some iron filings and some gelatine, wool or other organic matter containing nitrogen and heat the mixture for 10 minutes in a small iron crucible supported by a triangle. Cool, extract the mass with water and filter. Acidify the solution with dilute sulfuric acid and add a drop of ferric chloride(?).

Repeat the experiment, using only potassium carbonate and iron without the organic matter(?)

What complex cyanide is used in silver plating? Does hydrogen sulfide precipitate iron from an alkaline solution of potassium ferrocyanide?

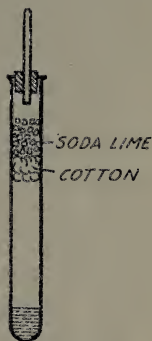


Fig. 29.

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## CHAPTER XIV

### ORGANIC COMPOUNDS

**74. Ethyl Alcohol.**—Heat 150 cc. of water to boiling in a granite dish. Put 75 grams of corn meal into the water in small portions while continuing to boil the liquid, stirring vigorously with a wooden stick or glass rod. After boiling for a short time allow the mixture to cool to 70° and stir into it 10 grams of ground malt. Keep the temperature at 65° to 70° for a few minutes till the thick pasty liquid becomes

thinly fluid, indicating the transformation of the starch into maltose(?). Transfer the liquid to a 500-cc. flask, fill the flask nearly full with water, bring the temperature to 25° and add one-fourth of a cake of compressed yeast which has been previously rubbed up with a little water. Mix thoroughly, stopper the flask loosely with cotton, or cover it with a watch-glass, and allow it to stand for 2 or 3 days, best at a temperature of about 20°. Explain what happens.

Put 5 cc. of lime water in a test-tube. Pour some of the carbon dioxide in the flask above the fermenting liquid into the test-tube, without pouring out any of the liquid. Put the thumb over the mouth of the tube and shake vigorously(?). Connect the flask with a condensing tube (12(a)). Distil and collect 50 cc. of the distillate in a 100-cc. flask. A Liebig's Condenser is most convenient for this purpose, but if this is not available the steam may be condensed by running cold water over the smaller flask or by immersing it in water which is changed from time to time as it becomes warm. Distil the condensed liquid from the smaller flask in a similar manner and collect 10 to 20 cc. of the distillate. Repeat till the first portions distilling over consist of alcohol strong enough to burn. What application is made of this process?

**75. Acetic Acid. Citric Acid.**—Prepare 250 cc. of a tenth normal sodium hydroxide by diluting 10 cc.(?) of a 10 per cent. solution of sodium hydroxide solution to that volume. Fill a burette with the alkali and titrate 10 cc. of vinegar with it, adding a few drops of phenolphthalein as an indicator. Calculate the per cent. of acetic acid in the vinegar.

Titrate a weighed or measured amount of lemon juice in the same way and calculate what per cent. of citric acid it contains.

**76. Soap.**—(a) *Preparation.*—Calculate how much sodium hydroxide will be required to saponify 5 grams of lard, or cotton-seed oil, or olive oil, on the supposition that it is glyceryl oleate (olein). Weigh 5 grams of the fat in a porcelain dish, add the calculated amount of a 10 per cent. solution of sodium







hydroxide and boil till a homogeneous solution is obtained, adding more water if necessary.

Dilute the solution to 20 cc. To 5 cc. of the solution add 2 grams of salt(?).

(b) *Separation of Fatty Acids*.—Add dilute hydrochloric acid to 5 cc. of the solution(?).

(c) *Effect on Hard Water*.—Dilute 5 cc. of the soap solution to 100 cc. Put 100 cc. of hard water in a 200-cc. stoppered bottle. Add a little of the soap solution and shake(?). Add a little more of the soap solution and shake again till a permanent froth is obtained(?). Repeat the experiment with distilled water, noting the volume of the soap solution required in the two cases. Could this process be used as a quantitative measure of the hardness of water?

(d) *Formation of an Emulsion*.—Put 10 cc. of water and 1 cc. of kerosene in a test-tube, place the thumb over the mouth of the tube and shake vigorously. Allow the tube to stand for a moment(?). Add a little of the soap solution and shake again(?). What is the connection between this experiment and the ordinary use of soap? This emulsion (1 part of oil to 4 parts of soapy water) is used to kill various kinds of bugs which infest plants.

**77. Starch—Glucose—Sugars.**—(a) *Starch Iodide*.—Recall 47(b). The blue color may be used either as a test for iodine or as a test for starch.

(b) *Starch Paste—Glucose*.—Take 2 grams of starch in a small beaker, mix it to a creamy mixture with a small quantity of water and pour over it, while stirring with a glass rod, 20 cc. of water which has been heated to boiling in a test-tube.

Add to the paste 1 cc. of dilute sulfuric acid (25 per cent.) and boil very gently in a flask, having a small watch-glass cover over its mouth, for  $\frac{1}{2}$  hour or longer, adding more water as it evaporates. Add  $\frac{1}{2}$  gram of calcium carbonate(?), warm for a short time, filter, and evaporate the filtrate to about 5 cc., noticing the odor(?). Taste the solution(?) and save it for (c).

(c) *Fehling's Solution—Glucose—Invert Sugar.*—Dissolve 3 grams of blue vitriol,  $(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})$  and 1.5 grams of cream of tartar,  $\text{KHC}_4\text{H}_4\text{O}_6$  in 45 cc. of water. Add 55 cc. of a 10 per cent. solution of sodium hydroxide. The deep blue solution is called Fehling's solution.<sup>1</sup>

Put 5 cc. of water in each of three test-tubes. To the first add a few drops of the solution from (b), to the second a few milligrams of cane sugar and to the third a few milligrams of cane sugar and  $\frac{1}{2}$  cc. of dilute hydrochloric acid. Boil the last solution for a few minutes.

Take 5 cc. of Fehling's solution in a test-tube, dilute it with 5 cc. of water, heat the liquid to boiling and add a little of the first solution(?). Repeat with the second and third solutions(?). Solutions of maltose and lactose may also be tested, if these are available.

(d) *Refining Sugar.*—Recall 67(d).

**78. Dyes.**—(a) *Indigo.*—Put 0.1 gram of indigo, 1 gram of green vitriol (copperas, or ferrous sulfate,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ), 1 gram of slaked lime, and 20 cc. of water in a large test-tube. Heat the mixture to boiling(?) and filter. Dip a piece of white cotton cloth in the solution and expose the cloth to the air. Explain the change that takes place.

(b) *Methyl Orange—Mordants.*—Dissolve 0.5 gram of methyl orange in 50 cc. of water. Prepare a second solution of 3 grams of alum or aluminium sulfate in 50 cc. of water. Take two pieces of white cotton cloth. Dip the first in the solution of methyl orange and allow it to dry. Dip the second in the solution of alum, squeeze out most of the solution and then dip it in the solution of methyl orange and allow the cloth to dry. Wash both pieces of cloth thoroughly with water(?).

<sup>1</sup> For quantitative work a more accurate formula from some book on food or sugar analysis should be used.





## CHAPTER XV

## SILICON—BORON

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**79. Silicon—Hydrogen Silicide.**—Mix 1 gram of *very fine* sand with the amount of magnesium powder required to reduce it to silicon and combine with the latter to form magnesium silicide. Put the mixture in a small test-tube and heat it till the reaction(?) has taken place. Allow the product to cool, break the tube and throw some of the product into a beaker containing 5 cc. of concentrated hydrochloric acid(?). Write equations.

(b) *Soluble Glass—Colloidal Silicic Acid.*—Mix 1 gram of infusorial earth ("kieselguhr") with 4 grams of a mixture of equal parts of sodium and potassium carbonates. Put the mixture in an iron crucible, 2.5 to 3 cm. in diameter and heat the crucible, if necessary over a blast lamp, till the mass is fused and effervescence(?) ceases. Pick up the red-hot crucible with crucible tongs or forceps and dip the bottom in cold water. This will cause the iron to contract before the melted silicate solidifies and as the latter cools it will usually separate from the iron so that it can be removed from the crucible in a solid cake. Powder the material in a mortar and dissolve it by digesting it in a beaker with 25 cc. of cold water. If the cake does not separate from the crucible it may be dissolved by long digestion in the crucible.

Divide the solution in two portions. To one portion add 5 cc. of concentrated hydrochloric acid slowly, drop by drop, stirring the solution(?). To the other portion add 5 cc of concentrated hydrochloric acid all at once(?).

Evaporate the first portion to dryness, moisten the residue with hydrochloric acid, add water and filter the solution(?).

**80. Boron.**—(a) *Borax Glass as an Acid Anhydride.*—Take a piece of platinum wire about 0.1 mm. in diameter and make a loop by wrapping the end of the wire around the point of a lead

pencil once *without crossing*. Heat the wire for a moment in the flame of the Bunsen burner and dip it in some powdered borax. Heat again till the borax melts to a clear glass. Dip the bead in a very dilute solution of cobalt nitrate or cobalt chloride and heat again(?). Prepare a new bead, dip it in a solution of a copper salt and heat, taking care to hold it at the side of the flame, in such a manner that the bead is exposed to the air on one side and an oxidizing effect is produced. After noting the color of the bead adjust the openings at the base of the burner and the size of the flame in such a manner that a faint luminous tip is obtained just above the blue cone in the center of the flame. Heat the bead in this reducing, luminous tip of the flame, until a new and quite different color is obtained(?).

What technical use is made of the solubility of iron oxide in borax glass? What use is made of similar colors of silicate glasses?

(b) *Boric Acid*.—Dissolve 5 grams of borax in 15 cc. of hot water, in a large test-tube or small beaker. Add enough concentrated hydrochloric acid to furnish the chlorine required to combine with the sodium of the borax, on the supposition that each cubic centimeter of the acid contains 0.4 gram of hydrochloric acid,  $\text{HCl}$ . Allow the solution to cool(?). What are the uses of the compound? Write the equation.

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## CHAPTER XVI

### REVERSIBLE REACTIONS—EQUILIBRIUM— IONIZATION

**81. Effect of Removing a Product upon the Equilibrium of Reacting Substances.**

(a) *Volatility*.—Illustrate by experiments with the following mixtures:

Salt and concentrated sulfuric acid.

Sodium carbonate and hydrochloric acid.







Ammonium chloride and ammonia.

Give other illustrations.

(b) *Insolubility, or Differences in Solubility.*—Illustrate with the following mixtures:

Silver nitrate and sodium chloride.

Acid sodium sulfate and concentrated hydrochloric acid (compare with (a)).

Copper sulfate and sodium hydroxide.

Give other illustrations.

(c) *Effect of a Common Ion.*—Take 5 cc. of a solution of lead nitrate and add 1 cc. of dilute hydrochloric acid(?). Pour off the mother liquor and wash the precipitate three or four times by decantation. Shake the purified lead chloride with water for a short time to secure a nearly saturated solution. Pour off the solution and add to it some dilute hydrochloric acid(?). What is meant by “solubility product?” Does a solution of lead nitrate cause a precipitate in the solution of lead chloride?

(d) *Slight Ionization.*—Recall experiments in neutralization.

(e) *Reduction of Ionization by the Formation of a Complex Ion.*—Try the effect of ammonium sulfide on a solution of ferrous sulfate and on a solution of potassium ferrocyanide(?).

Try the effect of sodium hydroxide on copper sulfate and on a solution of copper sulfate to which a little cream of tartar,  $\text{KHC}_4\text{H}_4\text{O}_6$ , or Rochelle salt,  $\text{KNaC}_4\text{H}_4\text{O}_6$ , has been added(?).

**82. Degree of Ionization.**—(a) *Salts—Effect of Dilution.*—Arrange a 50-cc. beaker with two copper electrodes on opposite sides, bent over the edges so that their relation to each other is not altered by stirring the solution in the beaker. Connect the electrodes in series with a dry cell and a suitable ammeter. Put 40 cc. of water in the beaker and by means of a pipette introduce 10 cc. of a saturated solution of copper sulfate. After noting the reading of the ammeter, stir the solution and read again(?).

(b) *Acids.*—Prepare approximately tenth normal solutions of acetic, oxalic and hydrochloric acids. Prepare, also, a

solution containing 6 grams of potassium iodide and 1 gram of potassium bromate in a liter.

Titrate 10 cc. of each of the acid solutions with a tenth normal solution of sodium hydroxide (55 and 75) to make sure that they have been properly prepared.

Put 10 cc. of the iodide-bromate solution in each of three test-tubes. Add 1 cc. of the acetic acid to the first, 1 cc. of the oxalic acid to the second and 1 cc. of the hydrochloric acid to the third(?). Tabulate the results.

(c) *Alkalies*.—Put 5 cc. of a solution of magnesium chloride in each of three test-tubes. Add some ammonia to the first, some ammonium chloride and ammonia to the second and some sodium chloride and sodium hydroxide to the third. Explain the results, taking account of the effect of the ammonium chloride on the ionization of the ammonium hydroxide.

(d) *Indicators*.—Dissolve 0.5 gram of disodium phosphate in 50 cc. of water and divide the solution into two equal parts. Titrate one portion with tenth normal hydrochloric acid, using phenol phthalein as an indicator. Titrate the other, with methyl orange as the indicator(?). Explain the difference.

The end points are not sharp.

(e) *Hydrolysis*.—Test solutions of sodium carbonate and of ferric chloride with litmus paper(?).

(f) *Application of These Principles. Qualitative Analysis for Acid Radicals or Anions*.—Put in a series of test-tubes 1 cc. of solutions containing sodium, potassium or ammonium salts of the following acid radicals (anions). Chloride, nitrate, hypochlorite, borate, carbonate, sulfate, oxalate, chromate, sulfide and iodide. Add to each solution a drop of a solution of silver nitrate and record the results, noting the colors of the precipitates, when formed. Add a little dilute nitric acid to each tube and note the results again.

Repeat the experiments using barium chloride instead of silver nitrate and dilute hydrochloric acid in place of nitric acid.





On the basis of the results classify the acids in the following groups:

1. Acids whose silver salts are insoluble in water and in dilute nitric acid.

2. Acids whose silver and barium salts are insoluble in water but soluble in dilute nitric acid.

3. Acids whose silver and barium salts are insoluble both in water and in dilute acids.

4. Acids whose silver and barium salts are soluble in water.

Having classified the acids recall for each acid some property by which it may be further identified.

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## CHAPTER XVII

### ALKALI METALS

**83. Sodium.**—(a) *Properties of Sodium.*—Recall **23(a)**.

(b) *Crystallization of Sodium Chloride.*—Recall **13(b)**.

(c) *Sodium Sulfate.*—Recall **30**.

(d) *Sodium Nitrate—Reduction.*—Recall **60**.

(e) *Sodium Thiosulfate.*—Recall **54**.

(f) *Sodium Carbonate—Hydrolysis.*—Recall **82(e)**.

(g) *Sodium Bicarbonate—Ammonia Soda Process.*—Shake 10 grams of salt with 25 cc. of a 10 per cent. solution of ammonia as long as any seems to dissolve. Pour off or filter the solution into a 100-cc. bottle having a stopper bearing two tubes bent and arranged as shown in Fig. 30. Pass carbon dioxide slowly from a Kipp generator into the solution through *A* until a rod which has been dipped in limewater shows that some of the gas is escaping at *B*. Close *B* with a short piece of rubber tubing closed at one end. The carbon dioxide will now enter the bottle only as it is absorbed by the solution, if the connections are tight. It may be some time before the sodium bicarbonate begins to separate. When no more carbon dioxide enters through *A* and the deposition of the



sodium bicarbonate appears to be complete, separate the salt from the solution by filtration, wash it with successive small quantities of water and examine its properties.

(h) *Baking Powder*.—Mix 1 gram of sodium bicarbonate with the calculated amount of cream of tartar,  $\text{KHC}_4\text{H}_4\text{O}_6$ , required to form Rochelle salt,  $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot \text{H}_2\text{O}$ . Add some water to the mixture(?). Explain the use as baking powder. Why do not the dry salts react with each other?

(i) *Sodium Hydroxide*.—Recall 23. Take 2 grams of lime in a small beaker, add about 3 cc. of water and allow it to stand till the lime is slaked as shown by its falling to a powder. Dis-

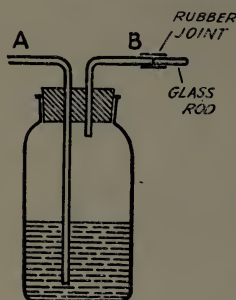


FIG. 30.

solve 4 grams of dry sodium carbonate in 30 cc. of water, add the lime, stir, and allow the mixture to settle till a part of the clear solution can be poured off into a test-tube. Test the solution of sodium hydroxide and also a part of the original solution with dilute hydrochloric acid. Take 5 cc. of a clear solution of calcium sulfate in each of two test-tubes. To one add some of the solution of sodium hydroxide and to the other some of the solution of sodium carbonate.

(j) *Soluble Glass*.—Recall 79(b).

(k) *Borax*.—Recall 80(a).

**84. Potassium.**—(a) *Wood Ashes—Potassium Carbonate*.—Mix 5 grams of wood ashes with 15 cc. of water. Filter, evaporate the solution to dryness in a porcelain dish and examine the residue. How could potassium hydroxide be prepared from it? Soft soap?

(b) *Potassium Hypochlorite*.—Recall 39.

(c) *Potassium Chlorate*.—Recall 41.

(d) *Potassium Perchlorate*.—Recall 42. Also, take 1 cc. of a solution of potassium chloride, and add one or two drops of a solution of perchloric acid(?). What other salts of potassium are difficultly soluble?





(e) *Potassium Nitrate*.—Take 8.5 grams(?) of sodium nitrate,  $\text{NaNO}_3$ , and 7.4 grams of potassium chloride and prepare some saltpeter from the mixture. Make use of the fact that sodium chloride dissolves in about three parts of either hot or cold water while saltpeter dissolves in less than its own weight of water at  $80^\circ$  but requires four parts of water to dissolve it at  $20^\circ$  and still more at lower temperatures.

(f) *Gunpowder*.—Mix intimately 1 gram of sulfur, 1 gram of charcoal and 3 grams of saltpeter. Ignite some of the mixture on a piece of sheet iron or sheet tin(?). Why does ordinary gunpowder burn more rapidly than this mixture? Dissolve the residue in water, filter and add to the solution a drop of a solution of ferric chloride or lead nitrate, also test the effect on a silver coin.

**85. Ammonium.**—(a) Recall 56(d) and 82(c).

(b) *Volatility of Ammonium Salts*.—Put 0.1 gram of ammonium chloride in a dry test-tube and heat it(?). Heat ammonium sulfate or phosphate and explain the difference.

(c) *Ammonium Sulfide*.—Take 1 cc. of a solution of ammonium hydroxide,  $\text{NH}_4\text{OH}$ , and pass hydrogen sulfide into it for a short time(?). Demonstrate the presence of ammonium sulfide in the solution. What is the effect of hydrochloric acid on it? How can ammonium hydrogen sulfide and ammonium polysulfide be prepared?

**86. Flame Colors.**—*Spectroscope*.—Fuse a short piece of thin iron or platinum wire into the end of a short glass rod or glass tube, clean it by dipping it repeatedly in dilute hydrochloric acid (2(d)) and heating it till it no longer colors the flame. Dip the wire in a solution of potassium chloride and hold it in the flame(?). Repeat with sodium, lithium, calcium, strontium and barium chlorides. The wire must, of course, be cleaned each time. If a spectroscope is available, examine the spectrum of each metal.

## CHAPTER XVIII

## COPPER GROUP—ANALYSIS

**87. Copper.**—(a) *Action of Acids on Copper.*—Recall **23(c)** **57(b)** and **52(a)**.

(b) *Copper Hydroxide—Copper Oxide.*—Dilute 1 cc. of a solution of copper sulfate,  $\text{CuSO}_4$ , to 5 cc. and add sodium hydroxide(?). Heat the solution to boiling(?).

(c) *Cuprous Chloride—Cuprous Oxide.*—Put  $\frac{1}{4}$  gram of cupric chloride in a test-tube, add an equal weight of copper powder and 3 cc. of concentrated hydrochloric acid. Warm gently till the solution becomes colorless. Pour the solution into a small beaker containing 15 cc. of water. Allow the cuprous chloride which is precipitated to settle, pour off the liquid and add a solution of sodium hydroxide to the residue(?). What is formed?

**88. Electromotive Series of Metals.**—Prepare strips of iron, tin, copper, zinc, lead and aluminium, 1 cm. wide and 5 cm. long. Attach to the end of each a piece of fine copper wire 20 to 30 cm. in length. By means of a dry cell, whose carbon pole is positive, determine how the current must be applied to a galvanometer<sup>1</sup> to cause the needle to move to the right.

Put some water in a small beaker and add a few drops of sulfuric acid. Connect the copper wires which are attached to two strips of different metals to the binding posts of the galvanometer and then dip the metals in the dilute acid, taking care that neither the metals nor the wires touch each other. Notice which way the needle of the galvanometer moves and determine in this way which metal is positive with reference to the other. If the galvanometer is of such a form that the needle can move only to the right it may, of course, be necessary to reverse the connections before a result is obtained.

<sup>1</sup> The pocket tester used in testing dry cells is suitable.







Test all of the metals systematically and prepare a table with the most positive metal at one end and the most negative at the other and the others in proper sequence between.

Repeat the experiment using a dilute solution of sodium hydroxide in place of the solution of sulfuric acid.

In making out the table it must be remembered that the metal which gives up positive ions to the solution is called electropositive. Thus in the dry cell the zinc is electropositive and the carbon electronegative with reference to the solution of ammonium chloride in the cell. With reference to the current flowing through the wires the carbon is positive and the zinc, negative. The former relation is used in the table.

**89. Silver-Photography.**—Float a piece of writing paper 7 cm. square on a 1 per cent. solution of silver nitrate and then on a 1 per cent. solution of salt with the briefest possible exposure to the light. Allow the paper to dry in the dark. Put the paper on a board, place on it the leaf of a tree, cover with a piece of glass and expose to diffused daylight, or, better to direct sunlight till the paper around the leaf has turned dark. Place the paper in a 5 per cent. solution of sodium thiosulfate and after some minutes wash the paper thoroughly with water and allow it to dry(?).

**90. Separation of Lead, Silver and Mercurous Mercury,** metals whose chlorides are nearly insoluble. Try the following experiment with 3 cc. of a solution of lead nitrate. Add some dilute hydrochloric acid, allow the precipitate to settle, pour off the solution, add 5 cc. of water, allow to settle, pour off and repeat a second time. Add to the precipitate 5 cc. of water, boil and pour off the solution into a clean test-tube and notice whether anything crystallizes from the solution on cooling. What are these crystals? Compare with **81(c)**. Repeat the same experiments with a solution of silver nitrate. Add some ammonia to the precipitate(?). Test the solution by adding nitric acid(?).

Repeat the experiments with a solution of mercurous nitrate.

Record the results obtained and by studying them devise

a method for separating and detecting the three metals when all are present. Prepare a solution containing the metals and demonstrate their separation.

**91. Separation of Mercury, Lead, Copper and Bismuth,** metals whose sulfides are insoluble in dilute acids. Recall **51(d)**. Take 3 cc. of a solution of mercuric chloride and pass hydrogen sulfide through the solution. Filter on a small filter supported in a funnel. Wash the precipitate five or six times by filling the filter with water and allowing the latter to run through (3). Rinse the precipitate back into the test-tube, allow it to settle and pour off the water. Boil the precipitate with dilute nitric acid, then add some hydrochloric acid and boil again(?). To the solution add a solution of stannous chloride,  $\text{SnCl}_2$ (?). The precipitate is either mercurous chloride or metallic mercury, according to the amount of stannous chloride used.

Repeat the first part of the above experiments, using a solution of lead nitrate. Does the lead sulfide dissolve in the nitric acid? Add some dilute sulfuric acid, pour the solution into a porcelain dish and evaporate nearly to dryness, but not after fumes of sulfuric acid appear. When cold, rinse back into a test-tube and notice the precipitate(?).

Repeat the experiments again with solutions of copper sulfate and of bismuth chloride. After the evaporation with sulfuric acid add ammonia to the solution(?). Filter off the precipitate of bismuth oxyhydroxide,  $\text{BiOOH}$ , dissolve it on the filter by dropping dilute hydrochloric acid over it and allowing the solution of bismuth trichloride,  $\text{BiCl}_3$  to drop into a beaker of water(?).

Devise a method of separating the four metals. Submit this to the criticism of an instructor and after approval apply it to a solution containing all four metals.





## CHAPTER XIX

## ALKALI EARTH METALS

**92. Calcium.**—(a) *Recall 76(c)*. Prepare a solution of castile soap by dissolving 2 grams in 200 cc. of water.

Put 100 cc. of an ordinary hard water in a 200-cc. flask, or bottle. Add 5 cc. of the soap solution and shake vigorously. Allow the bottle to stand for a moment and if a permanent foam does not remain add the soap solution, 5 cc. at a time, till a permanent foam is secured.

Boil 200 cc. of the water vigorously for 10 minutes. Replace the water which has evaporated with distilled water, filter and determine the amount of the soap solution required to produce a foam in 100 cc., as before.

Shake 1 gram of plaster of Paris,  $\text{CaSO}_4$ , with 200 cc. of water and filter. Divide the filtrate into two equal portions. Determine, as before, the hardness of one portion as it is and of the other after boiling(?).

(b) *Plaster of Paris*.—Mix 2 grams of plaster of Paris with water to a very thick cream. Allow the mixture to stand for a few minutes(?).

(c) *Cement*.—Mix some cement with a little water and allow the mixture to stand overnight(?). What are the proportions of cement and water used by engineers(?).

(d) *Calcium Carbide*.—Recall 69(c).

(e) *Calcium Oxalate*.—Dilute 1 cc. of a solution of calcium chloride to 10 cc. Add a solution of ammonium oxalate. Test the solubility of the precipitate in water, acetic acid and dilute hydrochloric acid. Apply the principles of ionization of acids and of the solubility product in explaining the results.

**93. Barium.**—(a) *Difficulty Soluble Salts*.—Take 1 cc. of a solution of barium chloride in each of three test-tubes. Add to one a solution of sodium carbonate(?), to the second dilute sulfuric acid(?) and to the third a solution of potassium dichro-

mate(?). The precipitate in the last case is the chromate, not the dichromate. Test the solubility of the precipitates in water, acetic acid and hydrochloric acid and discuss the results.

(b) *Determination of Sulfur in a Sulfate.*—Weigh about 1 gram of copper sulfate accurately. Dissolve in 300 cc. of hot water and add two or three drops of dilute hydrochloric acid. Heat the solution to boiling and add slowly, drop by drop, a solution of barium chloride, stirring the solution with a glass rod. Continue to add the barium chloride till, after allowing the solution to settle for a short time, the addition of a drop of the solution of barium chloride causes no turbidity. Continue to heat the solution over a low flame, stirring occasionally, until the precipitate settles quickly after stirring, indicating that it has become comparatively coarse grained and crystalline. Allow to settle and pour off the clear solution through a 7-cm. filter. Add about 50 cc. of distilled water and allow to settle and pour off the solution through the filter and repeat this a second time. Then rinse the precipitate on to the filter completely and after the water has run through apply more water at the edge of the filter, let this run through and repeat till a little of the filtrate collected in a clean test-tube gives no precipitate when a drop of a solution of silver nitrate is added to it. What does this indicate? When the water has thoroughly drained away from the precipitate, fold the filter together at the top and hold it in the flame of a Bunsen burner with a pair of clean forceps until the filter is dry and begins to char. Then put the filter in a porcelain crucible which has been accurately weighed and which is supported in an inclined position on a triangle. Heat at first gently and finally with the full heat of the burner till the filter is burned and the precipitate is white. Cool and weigh. From the weight of the precipitate calculate the amount of sulfur which it contains and then the per cent. of sulfur in the copper sulfate. Compare this with the theoretical per cent., remembering that copper sulfate contains water of hydration or crystallization.







## CHAPTER XX

## MAGNESIUM GROUP

**94. Magnesium.**—(a) *Magnesium Carbonate.*—Weigh a porcelain crucible accurately. Put in it about 1 gram of magnesium carbonate,  $\text{MgCO}_3$ , and weigh again. Cover the crucible, place it on a triangle and heat it for 10 minutes over the full flame of a Bunsen burner. Cool and weigh. Assuming that the loss is carbon dioxide, calculate the molecular weight of magnesium oxide.

(b) *Magnesium Hydroxide.*—Recall 82(c).

(c) *Preparation of Magnesium Sulfate.*—Add 20 grams of a dolomitic limestone to somewhat less than the calculated amount of dilute sulfuric acid, which has been further diluted with two volumes of water. Boil(?), filter and evaporate the filtrate far enough so that the magnesium sulfate will crystallize on cooling.

**95. Zinc.**—(a) *Action of Acids on Zinc.*—Recall 23(c).

(b) *Zinc Oxide.*—Recall 68(c).

(c) *Zinc Sulfide.*—Recall 51(d). What advantages has zinc oxide as a pigment?

(d) *Lithopone.*—Mix 2 grams of barium sulfate with 2 grams of powdered charcoal. Put the mixture in a porcelain crucible, support it on a triangle and heat it for 10 minutes with the blast lamp(?). When the crucible is cold, extract the mass with hot water, filter, and add the solution to a solution of zinc sulfate(?).

**96. Mercury.**—(a) *Mercuric Oxide.*—Recall 14(b).

(b) *Corrosive Sublimate and Calomel.*—*Mercurous Oxide.*—By means of a small glass tube drawn to a fine capillary, transfer 0.3 to 0.5 gram of metallic mercury to a dry test-tube and weigh it. Put in the calculated amount, or a little more, of corrosive sublimate (mercuric chloride,  $\text{HgCl}_2$ ) and heat the mixture till it sublimes in the upper part of the tube. When the tube is cold, loosen the material from the walls of the

tube and boil it with water to remove the unchanged mercuric chloride.

Pour off the solution and add to it a solution of sodium hydroxide(?). Add sodium hydroxide to the residue, also(?).

(c) *Reduction of Mercuric Chlorid by Stannous Chloride.*—Recall 91.

(d) *Analysis of Solutions Containing Mercury.*—Recall 90 and 91.

(e) *Nessler's Reagent.*—Prepare the reagent by the directions given in some book on water analysis. Test the distilled water of the laboratory with the reagent. Prepare a solution of ammonium chloride which contains 0.001 mg. of nitrogen in 1 cc. Put 50 cc. of this solution in a large test-tube and add 1 cc. of the Nessler's Reagent.

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## CHAPTER XXI

### ALUMINIUM

97. (a) *Sodium Aluminate.*—Recall 27.

(b) *Potash Alum.*—Calculate the amount of potassium sulfate required to combine with 5 grams of aluminium sulfate of the sort used for the purification of water, on the supposition that it contains 17 per cent. of aluminium. Dissolve these quantities of the two substances in 15 to 20 cc. of water, filter, if necessary, and allow the salt to crystallize. What is the form of the crystals? Ammonium sulfate may be used in place of potassium sulfate(?).

(c) *Clarification of Water with Alum.*—Mix a little clay with 500 to 700 cc. of hydrant or well water. Allow the coarser particles to settle and divide the turbid liquid into two equal portions, in flasks or beakers. Add to one 1 or 2 cc. of a solution of alum and after mixing thoroughly filter a few cubic centimeters of each portion(?). Allow the remainder of each to stand for some time. Explain. What is the practical application?





(d) *Baking Powder*.—Mix 2 grams of sodium bicarbonate with the theoretical amount of powdered alum. Put the mixture in a beaker and add 50 cc. of water(?). After the effervescence has ceased notice the precipitate(?) suspended in the solution. Write the equations for the reactions. Explain the practical application.

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## CHAPTER XXII

## TIN—LEAD

98. **Tin.**—(a) *Rusting of Iron in Contact with Tin*.—Scour a piece of thin sheet iron with sand and water till its surface is bright on both sides. Cut three pieces about 2 cm. square and lay them on the bottom of a dish containing water, taking care that they are not in contact. Place a small piece of tin on one of the pieces of iron and a piece of zinc on another. Allow them to remain in the water over night(?).

(b) *Stannous Chloride*.—Calculate the amount of concentrated hydrochloric acid required to dissolve 10 grams of tin on the basis that 1 cc. of the acid contains 0.4 gram HCl. Measure 50 per cent. in excess of the calculated amount and dissolve 10 grams of tin in this, warming gently in a beaker covered with a watch-glass. When the solution is complete, allow the solution to settle for a few minutes and decant it from any residue which remains, while still warm. What is the formula of the hydrated stannous chloride which crystallizes on cooling?

Recall the effect of stannous chloride on mercuric chloride.

Add a dilute solution of potassium permanganate to a dilute acid solution of stannous chloride(?). Write the equations.

Repeat with potassium dichromate.

(c) *Stannic Chloride*.—Put 2 grams of tin in a dry test-tube, immerse this nearly to its lip in a beaker of cold water and pass chlorine, dried by passing it through a calcium chloride

tube, into the tube till the tin is converted into stannic chloride.

Support the test-tube with a clamp on a retort stand. By means of a perforated cork, which rests on (not in) the mouth of the test-tube, support a thermometer so that the bulb is 2 to 3 cm. above the stannic chloride in the bottom. With a very low flame boil the chloride at such a rate that the vapors rise only one-half or two-thirds of the height of the tube and note the boiling point.

Pour a few drops of the stannic chloride into water(?).

(d) *Fireproofing Cotton Goods*.—Put 2.25 grams(?) of crystallized stannous chloride in a small beaker, add 2.5 cc. of concentrated hydrochloric acid, 3 cc. of water and 1 cc. of nitric acid (sp. gr. 1.20). Warm the mixture gently as long as nitric oxide(?) escapes. Add a 10 per cent. solution of sodium hydroxide till the precipitate which forms at first is just dissolved(?).

Put a piece of cotton cloth 6 cm. square into the solution and make sure that it is thoroughly moistened. Take it out of the solution with a glass rod, allow it to drain for a moment and then put it into a 10 per cent. solution of ammonium sulfate(?). After 10 or 15 minutes remove it, wash it with water, allow it to dry and test its inflammability.

**99. Lead.**—(a) *Fusibility of Tin, Lead and Zinc*.—Place pieces of tin, lead and zinc, each weighing about 1 gram, 2 cm. apart in the form of a triangle on a thin piece of sheet iron or sheet tin supported by the ring of a retort stand. Apply a small flame immediately below the center of the triangle and increase the flame gradually till the plate is red hot, raising the ring of the retort stand or lowering the burner, if necessary, to secure the best effect of the flame. Notice the order in which the metals melt and also the effect of further heat on each. Notice also the color of the oxides, both when hot and when cold.

(b) *Lead Nitrate*.—Dissolve 0.1 gram of metallic lead in 2 or 3 cc. of dilute nitric acid(?). What tests may be applied







to this solution to show the presence of lead? How could the metallic lead be recovered? Will lead dissolve in hydrochloric acid? In sulfuric acid?

(c) *Storage Battery*.—Connect two strips of lead with a battery giving a potential of 6 to 8 volts and dip the strips in a beaker containing dilute sulfuric acid(?). After some time connect the strips with the binding posts of a voltmeter or ammeter(?). Explain all of the phenomena, including a statement as to whether the strip which is the cathode during electrolysis (charging) becomes the positive or negative pole of the storage battery.

(d) *Lead Chloride*.—Recall 90.

(e) *Chrome Yellow*.—Dissolve 0.1 gram of white lead in dilute acetic acid(?). Add a little of a solution of potassium dichromate(?).

(f) *Chrome Green*.—Put 1 cc. of a solution of ferric chloride in a test-tube and add a few drops of a solution of potassium ferrocyanide(?). To the solution containing Prussian blue add some of the chrome yellow from the previous experiment(?).

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## CHAPTER XXIII

### CHROMIUM. MANGANESE

**100. Chromium.**—(a) *Potassium Chromate and Dichromate*.

—Fuse 3 grams of potassium hydroxide in a small iron crucible supported on a triangle in an inclined position. Add 0.5 gram of very finely powdered chrome iron ore. Heat for a half hour or longer, cool, digest the material with water and filter the solution(?).

Acidify a part of the solution with acetic acid(?) and add a few drops of a solution of lead acetate or lead nitrate(?).

Acidify another portion with hydrochloric acid and add some sodium sulfite(?) or stannous chloride(?). Write equations.

(b) *Chrome Alum*.—*Chromic Hydroxide*.—Add 1 cc. of dilute sulfuric acid and 0.5 cc. of alcohol to 5 cc. of a 10 per

cent. solution of potassium dichromate. Warm till the solution is of a pure green color(?) noticing the odor(?). Add ammonia to the solution(?). Write equations.

(c) *Chromic Anhydride*.—To 5 cc. of a concentrated solution of potassium dichromate add 5 cc. of concentrated sulfuric acid. Allow the mixture to cool slowly(?). If a piece of porous porcelain is available, some of the crystals may be separated by transferring them to it with a glass rod and allowing the piece to stand on a watch-glass in a dessicator, or closely covered in a beaker, till the liquid has been absorbed.

The solution containing the crystals is a very vigorous oxidizing agent and should not be thrown in a slop-jar containing dry paper, without previous dilution.

**101. Manganese.**—(a) *Potassium Manganate and Permanganate*.—Repeat the first part of **100**, using 1 gram of manganese dioxide in place of the chrome iron ore(?). Why is the solution obtained called chameleon solution?

Acidify some of the solution with sulfuric acid(?).

Recall purposes for which potassium permanganate has been used.

(b) *Permanganic Acid*.—To a few drops of a solution of manganous sulfate add 0.5 cc. of dilute nitric acid, 5 cc. of water and a little red lead or lead dioxide. Shake and allow to settle(?).

(c) *Manganese Dioxide as an Oxidizing Agent*.—Warm 0.1 gram of manganese dioxide with water, dilute sulfuric acid, and oxalic acid(?).

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## CHAPTER XXIV

### IRON, COBALT, NICKEL

**102. Iron.**—(a) *Combined Carbon in Cast Iron*.—Dissolve 0.5 gram of cast-iron borings in dilute hydrochloric acid, and notice the odor(?).

(b) *Graphite in Cast Iron*.—Dissolve 0.5 gram of cast iron





in 10 c.c. of nitric acid, (sp. gr. 1.20) in a beaker, dilute, filter and examine the residue(?).

(c) *Manganese in Cast Iron*.—Test the nitric acid solution from (b) for manganese according to 102(b).

(d) *Preparation of Copperas*.—Take 25 cc. of dilute acid (1:5 by volume, containing 25 per cent. of sulfuric acid) and 10 cc. of water. Add one-fourth more than the theoretical amount of iron filings. Warm gently till the evolution of hydrogen nearly stops. Filter the solution while warm, add a few drops of dilute sulfuric acid and allow the solution to cool and crystallize(?).

(e) *Properties of Ferrous Hydroxide*.—Dissolve a little ferrous sulfate in water and add a solution of sodium hydroxide. Notice the first color of the precipitate and the changes in color on exposure to the air(?). On account of the ease with which ferrous sulfate oxidises, a compact crystal should be used and the surface rinsed off before dissolving it. Does ferrous iron oxidise more easily in an acid or in an alkaline solution? Compare with the properties of manganese and chromium.

(f) *Oxidation of Ferrous Sulphate*.—*Ferric Hydroxide*.—Dissolve a little ferrous sulfate in water, add some dilute sulfuric acid and a little nitric acid and warm the solution(?). Add a solution of sodium hydroxide or of ammonium hydroxide(?).

(g) *Anhydrous Ferric Chloride*.—Put some small nails or iron filings or turnings 8 to 10 cm. from the end of a glass tube 30 cm. long and 10 to 15 mm. in diameter. Pass chlorine, dried with calcium chloride or concentrated sulfuric acid, through the tube and heat the iron gently. The operation should be carried out in a hood and any excess of chlorine should be led into a bottle containing sodium hydroxide and absorbed. Expose some of the product to the air(?).

Can anhydrous ferric chloride be obtained by evaporating a solution of the salt? Test the solution with litmus paper(?).

**103. Cobalt and Nickel.**—(a) *Complementary Colors of Cobalt and Nickel Salts*.—Take 1 cc. of a solution of cobalt

chloride and add a solution of nickel chloride or nickel nitrate, carefully, till the mixed solution becomes nearly colorless(?).

(b) *Sympathetic Ink*.—Draw a picture of a tree without leaves with a lead pencil, on a sheet of white paper. Draw leaves with a solution of cobalt chloride, using a pen. Dry the paper on a steam radiator, or on a water bath(?). What is the relation between the changes in color and the humidity of the air?







## PART II

### CLASS-ROOM EXERCISES

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#### SUGGESTIONS FOR THE STUDENT

The problems in the following pages are based upon principles discussed in the Textbook. It will be very helpful in solving the problems to read over those paragraphs of the Textbook which explain the topic involved. It will frequently be found necessary to refer to the text for data needed in the solution of a problem.

**1. Symbols** are to be regarded as a sort of "shorthand" language, widely used in chemistry to express compactly three things: (1) A symbol is used in place of the full name of an element, as for example H for hydrogen, Na for sodium. (2) A symbol standing by itself represents one atom of an element. Thus H represents one atom of hydrogen and 2H represents two atoms. (3) A symbol stands for the gram-atom of the element; that is for as many grams as there are units in the atomic weight. Thus Na stands for 23 grams of sodium.

**2. Formulas** are used in a similar manner to represent four distinct things: (1) It is an abbreviation for the name of a compound; thus HCl is the formula for hydrochloric acid and H<sub>2</sub> stands for hydrogen combined with itself. (2) A formula represents one molecule of a compound; thus HNO<sub>3</sub> represents one molecule of nitric acid and H<sub>2</sub> represents a molecule of hydrogen. It is to be observed that H<sub>2</sub> and 2H represent the same amount of hydrogen but when H<sub>2</sub> is written we understand that the two atoms of hydrogen are in combination with each other forming one molecule, while 2H stands merely for

two atoms of hydrogen, and it is generally understood that they are not combined with each other. (3) A formula represents a gram-molecule of the compound; thus  $\text{HCl}$  represents 36.5 grams of hydrochloric acid. (4) *If the substance is a gas*, the formula represents a gram-molecular volume of the gas; thus  $\text{HCl}$  represents a gram-molecular volume of  $\text{HCl}$  gas, that is 22.4 liters at  $0^\circ$  and 760 mm.

**3. Equations** are to be interpreted as a shorthand representation of the changes that take place during a chemical action and must be understood as showing three things: (1) Both the substances entering into the reaction and those resulting from the reaction are represented in the equation. Thus  $4\text{H}_2\text{O} + 3\text{Fe} = \text{Fe}_3\text{O}_4 + 4\text{H}_2$  means that water (or steam) reacts with iron producing the magnetic oxide of iron and hydrogen. (2) The equation also represents the relative quantities of the substances involved. Thus 4 gram-molecules ( $4 \times 18$  grams) of steam react with 3 gram-atoms ( $3 \times 56$  grams) of iron, producing one gram-molecule [ $(3 \times 56) + (4 \times 16)$  grams] of oxide and 4 gram-molecules ( $4 \times 2$  grams) of hydrogen. (3) Since the gram-molecule of any gas may be considered as occupying a volume of approximately 22.4 liters under standard conditions, the volumes of all *gases* involved in an equation may be predicted. Thus 4 gram-molecular volumes ( $4 \times 22.4$  liters) of steam will react with 168 *grams* of iron and there will be formed 232 *grams* of magnetic oxide and 4 gram-molecular volumes ( $4 \times 22.4$  liters) of hydrogen.

**4. Calculation of formulas** requires information concerning the relative proportion of the constituents and the atomic weights of the elements. From this data a proportion is made which expresses the relative weights of the combining substances. Now by factoring the terms of the proportion in such a manner that one factor is the atomic weight, it is easily seen what multiples of the other elements will be necessary to represent the composition of the substance. To illustrate: a compound containing 72.41 per cent. of Fe and

27.59 per cent. of O, has what formula? The ratio  $\frac{\text{Fe}}{\text{O}}$  is  $\frac{72.41}{27.59}$ . To obtain the relative number of atoms of iron and

oxygen we divide the members of this ratio by the atomic weights of the respective elements.  $72.41 \div 56 = 1.29$  and  $27.59 \div 16 = 1.72$ , so our ratio becomes  $\frac{56 \times 1.29}{16 \times 1.72}$ . Since we do not use fractions of an atom in expressing the formula of a compound, we must determine what simple whole numbers bear to each other the same relationship as 1.29:1.72. If the terms of this ratio are divided by the smallest member we get 1:1.33 which means that for every atom of iron there must be present one and a third atoms of oxygen; or expressed in simple whole numbers Fe:O::3:4. The complete statement is

$$\frac{\text{Fe}}{\text{O}} = \frac{72.41}{27.59} = \frac{56 \times 1.29}{16 \times 1.72} = \frac{56 \times 1}{16 \times 1.33} = \frac{56 \times 3}{16 \times 4}$$

Hence the formula is  $\text{Fe}_3\text{O}_4$ . It is to be observed that this compound might be any multiple of  $\text{Fe}_3\text{O}_4$  but we generally assume the simplest formula, unless additional information requires some other conclusion.

**5. Percentage composition** of a compound may be determined from its formula by calculating the per cent. of each element in its gram-molecule. The percentage of oxygen in  $\text{KMnO}_4$  is obtained by observing that oxygen makes up  $4 \times 16 = 64$  grams, while the total gram-molecule is  $39 + 55 + 64 = 158$  grams. Then if 64 parts of oxygen are found in 158 parts of potassium permanganate, the amount of oxygen in 100 parts of permanganate would be found from the proportion

$$64:158 = x:100 \text{ or } 40.5 \text{ per cent.}$$

**6. Valence** expresses the capacity of an element or group of elements for holding in combination other elements or groups. In order to express this holding power numerically a unit is needed and the combining capacity of the hydrogen atom is

used as a standard, its valence being one. Any single element or group which has the ability to combine with one atom of hydrogen has a valence of one. Thus from the formulas of the compounds  $\text{HCl}$  and  $\text{HNO}_3$  it is evident that both the atom  $\text{Cl}$  and the group  $\text{NO}_3$  have the same capacity for combining as the hydrogen atom, hence the valence of each is one. In similar manner the formulas  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ , and  $\text{CH}_4$  show us that the valence of oxygen is two, of nitrogen is three and of carbon is four. Further, any element which can occupy the same place as an atom of hydrogen has a valence of one. Thus, if the hydrogen of  $\text{HCl}$  is replaced by an atom of sodium giving the compound  $\text{NaCl}$  it is evident that one atom of sodium has taken the place of the hydrogen atom, hence its valence is one. In like manner the formulas  $\text{CaO}$ ,  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  show that the valence of calcium is two ( $\text{Ca}$  has replaced  $\text{H}_2$ ), of aluminium is three ( $\text{Al}_2$  has replaced  $3\text{H}_2$ ) and of silicon is four ( $\text{Si}$  has replaced  $2\text{H}_2$ ).

**The Valence of an Element may be Determined** in several ways:

1. By determining the number of hydrogen atoms with which the element will combine, as illustrated above.

2. By determining the number of hydrogen atoms which the element will replace. See above.

3. The position of an element in the Periodic Table frequently assists in learning its valence. An element in group one is univalent (copper is usually bivalent); an element in group two is bivalent; group three, trivalent; group four, quadrivalent (tin is sometimes, and lead is usually, bivalent); group five, either trivalent or pentavalent; group six elements have a valence of 2, 4 or 6 except oxygen, which may be considered as bivalent; in group seven, valences of 1, 3, 5 and 7 are found and in group eight the usual valences are 2 or 3.

**7. In Writing Equations** several steps may be employed:

1. Write the correct formulas for the factors, which are the substances entering into the reaction, and place the sign  $+$  between them. A knowledge of valence is required.



2. Write the sign = after the last factor. Sometimes the single arrow  $\rightarrow$  is used, and generally the double arrow  $\rightleftharpoons$  is used to indicate a reversible reaction.

3. Write the formulas for the products of the reaction, that is the substances formed in the reaction, observing valences carefully. The following suggestions are made to assist in determining what substances may be expected, when one substance reacts with another:

(a) When substances containing hydrogen and oxygen react, water is almost always one product of the reaction. Thus  $4\text{HCl} + \text{MnO}_2 = \text{MnCl}_2 + 2\text{H}_2\text{O} + \text{Cl}_2$ .

(b) An acid and a base neutralize each other to form a salt and water:  $\text{HCl} + \text{NaOH} = \text{NaCl} + \text{H}_2\text{O}$ .

(c) Radicals generally remain intact:  $\text{Zn} + \text{H}_2\text{SO}_4 = \text{ZnSO}_4 + \text{H}_2$ .

(d) Hydrogen has striking chemical affinity not only for oxygen, but for other non-metals like chlorine and for non-metallic radicals like  $\text{SO}_4$  and  $\text{NO}_3$ , forming such compounds as  $\text{HCl}$ ,  $\text{H}_2\text{SO}_4$  and  $\text{HNO}_3$ .

(e) Most metals will replace the hydrogen of acids forming salts:  $\text{Zn} + \text{HCl} = \text{ZnCl}_2 + \text{H}_2$ .

(f) When two substances in solution are brought together the usual reaction is a simple exchange, called double decomposition or metathesis. This tendency is increased if such an exchange results in the formation of a gas, an insoluble compound, or a slightly ionized substance. (See Textbook, p. 374 *et seq.*)

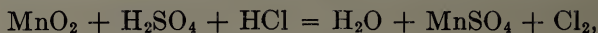
4. Having written the correct formulas for the factors and the products, the final step is to determine what coefficients must be employed in order to make the statement conform to the Law of Conservation of Matter. To illustrate: the expression  $\text{Fe} + \text{H}_2\text{O} = \text{Fe}_3\text{O}_4 + \text{H}$  says that iron reacts with water (or steam) to form the magnetic oxide of iron and hydrogen. This is, however, misleading because it would lead one to suppose that in the process two atoms of iron and three atoms of oxygen are created and one atom of hydrogen is destroyed.

The balanced equations must show the same number of atoms on both sides. Hence the complete expression would read  $3\text{Fe} + 4\text{H}_2\text{O} = \text{Fe}_3\text{O}_4 + 4\text{H}_2$ .

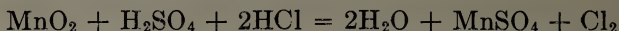
**8. Equations Involving More Than Two Factors** may be solved by (a) the same method or (b) by writing partial equations and then adding:

Write the equation for the reaction between  $\text{MnO}_2 + \text{H}_2\text{SO}_4 + \text{HCl}$ .

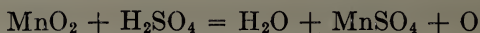
(a) The hydrogen and oxygen will unite to form water, leaving Mn,  $\text{SO}_4$  and Cl. These latter will combine to form  $\text{MnSO}_4$  or  $\text{MnCl}_2$  since metals have a strong affinity for non-metallic radicals. Oxidizing agents liberate chlorine from HCl (see Textbook, p. 122), so we would expect chlorine to escape leaving  $\text{MnSO}_4$  in solution. This would give



and balancing the equation, we get



(b) By the method of partial equations proceed in the following manner:

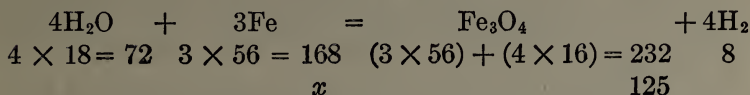


adding:  $\text{MnO}_2 + \text{H}_2\text{SO}_4 + 2\text{HCl} = 2\text{H}_2\text{O} + \text{MnSO}_4 + \text{Cl}_2$

**9. Problems Involving the Weights** of substances may be solved by the following steps: (1) Write the equation for the reaction involved, making sure that it is correctly balanced. (2) Write under each formula (or symbol) the weight it represents multiplied by the number of times it is taken in the equation. (3) Read the problem carefully and notice that you are asked to determine how much of a given substance, *A*, can be prepared from a definite weight of another substance, *B*. (4) Write the given weight of *B* under the formula for this substance in the equation and *X* under the formula for the substance *A*. (5) State the proportion and solve for *X*.



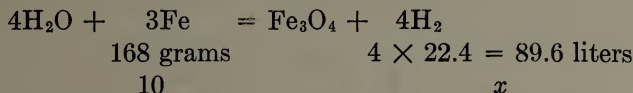
For example, if it is required to determine how much iron must be used in reaction with steam to form 125 grams of  $\text{Fe}_3\text{O}_4$  the record would appear as follows:



Since the equation shows that 168 grams of iron are required to produce 232 grams of the oxide, then  $x$  grams of iron will form 125 grams of magnetic oxide and

$$\begin{aligned}
 168:232 &= x:125 \\
 232x &= 21,000 \\
 x &= 90.5
 \end{aligned}$$

**10. Problems Involving Volumes of Gases** are solved in a similar manner, remembering that a gram-molecule of a gas occupies 22.4 liters. For example if it is desired to learn what volume of hydrogen could be liberated by the action of steam upon 10 grams of iron filings, the reasoning would be as follows:



Since 168 grams of iron will set free 89.6 liters of hydrogen then 10 grams of iron will free  $x$  liters of hydrogen:

$$\begin{aligned}
 168:89.6 &= 10:x \\
 x &= \frac{89.6 \times 10}{168} = 5\frac{1}{3} \text{ liters.}
 \end{aligned}$$

In the same way if we are required to learn what volume of steam enters into the reaction to liberate a certain volume of hydrogen, study of the equation shows that the volume of steam consumed is the same as that of the hydrogen formed since four gram-molecules of steam, occupying  $4 \times 22.4$  liters, will yield four gram-molecules of hydrogen, which also occupies 89.6 liters. Hence the equation itself shows that the volume

of steam consumed is the same as the volume of hydrogen formed, provided only that the two gases are measured at the same temperature and pressure.

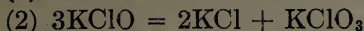
**Caution.**—Care is needed in getting the correct molecular formulas for gaseous substances appearing in the equations as elements.

**11. Problems Involving Formular Solutions** may be solved in a similar way by remembering that a gram-molecule of a substance represents one liter of its formular (or molar) solution. Thus  $\text{H}_2\text{SO}_4$  represents a gram-molecule of sulfuric acid, which is the amount of that acid to be found in one liter of its formular solution.

**12. Normal Solutions** differ from formular solutions in that a gram-molecule represents as many liters of the normal solution as the valence involved. Thus  $\text{HCl}$  and  $\text{NaOH}$  represent, respectively, one liter of a normal solution of hydrochloric acid and sodium hydroxide: while  $\text{H}_2\text{SO}_4$  and  $\text{Ca}(\text{OH})_2$  represent, respectively, two liters of normal sulfuric acid solution and calcium hydroxide solution.

**13. Problems Involving Percentage Strength** are usually stated in terms of weight and require the specific gravity of the solution. Thus it is desired to know how much  $\text{HNO}_3$  is contained in 100 c.c. of a solution which has a specific gravity of 1.2 containing 32.36 per cent. of  $\text{HNO}_3$ . By specific gravity of solids and liquids is meant the weight compared with the weight of an equal volume of water. Since 1 cc. of water weighs 1 gram, 1 cc. of a liquid whose specific gravity is 1.2 will weigh 1.2 grams. So 100 cc. will weigh 120 grams and if 32.36 per cent. of this solution is  $\text{HNO}_3$  then the total amount of  $\text{HNO}_3$  present will be  $100 \times 1.2 \times 0.3236 = 38.83$  grams.

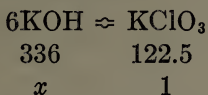
**14. Problems Involving Several Reactions** may be solved by writing all the equations, making sure that each one supplies enough of the intermediate product for the succeeding equation. To illustrate: How much  $\text{KOH}$  must be used to prepare 1 gram of  $\text{KClO}_3$ ? The equations involved are



Equation (2) needs 3KClO whereas (1) only provides one molecule so (1) should be multiplied by 3 thus



By studying these equations it is clear that 6 gram-molecules of KOH are used for every gram-molecule of KClO<sub>3</sub> made. In solving the problem then it is not necessary to consider the quantity of the intermediate substance, KClO, which is formed but we may write



Problems which involve several intermediate products may be solved by the same principle, if care is used in writing the equations.

**15. The Degree of Ionization** of an electrolyte may be calculated from the freezing point depression, by comparison with a non-electrolyte. If a milligram-molecule of sugar in 10 cc. freezes at  $-0.184^\circ$ , this may be considered as the *normal* freezing point for this concentration. A milligram-molecule of HCl in 10 cc. freezes at  $-0.355^\circ$ , an abnormally great depression of the freezing point, caused by the fact that some of the molecules have broken up into two ions, each of which has the same effect upon the freezing point as the original molecule. The excess depression due to ionization is 0.171, which indicates that it is ionized to the extent of  $\frac{171}{184}$

or 93 per cent. If each molecule of the electrolyte yields three ions, as for example,  $\text{H}_2\text{SO}_4 \rightleftharpoons 2\text{H}^+ + \text{SO}_4^{--}$ , then the excess depression, due in this case to two extra ions, must be divided by 2 in order to get the fraction ionized.

**16. Dissociation Constants** are calculated by the aid of the Mass Law formula  $\frac{[\text{C}_2] \times [\text{C}_3]}{[\text{C}_1]} = K$ , in which [C<sub>1</sub>] is the molar

concentration of the un-ionized molecules and  $[C_2]$  and  $[C_3]$  represent the molar concentrations of the ions. For example: Calculate the dissociation constant for 0.1N acetic acid which is 1.3 per cent. ionized. The molar concentrations of  $H^+$ ,  $[C_2]$ , and  $C_2H_3O_2^-$ ,  $[C_3]$ , is  $0.1 \times 0.013 = 0.0013$ ; the molar concentration of the un-ionized molecules  $[C_1]$  is then  $0.1 - 0.0013 = 0.0987$ . Substituting:  $\frac{(0.0013)^2}{0.0987} = 0.0000171$  or  $1.71 \times 10^{-5}$ .

If the electrolyte yields three ions then  $[C_3]$  is no longer equal to  $[C_2]$  but is twice as great, and since the effect is proportional to the product of the concentrations,  $[C_3]$  must be squared. Calculate the ionization constant for a solution containing 0.5772 grams  $Ca(OH)_2$  per liter, this solution being 90 per cent. ionized. It is evident from the ionization equation,  $Ca(OH)_2 \rightleftharpoons Ca^{++} + 2OH^-$ , that each dissociating molecule of  $Ca(OH)_2$  yields one  $Ca^{++}$  and two  $OH^-$ ; therefore  $[C_3]$  is twice  $[C_2]$ . Now 0.5772 grams of  $Ca(OH)_2$  per liter

represents a molar concentration of  $\frac{0.5772}{74} = 0.0078$ . If this is 0.9 ionized then  $[C_2]$  equal  $0.0078 \times 0.9 = 0.00702$ ,  $[C_3] = 0.01404$  and  $[C_1] = 0.1 \times 0.0078 = 0.00078$ . Substituting:

$$\frac{0.00702 \times (0.01404)^2}{0.00078} = 0.00177 \text{ or } 1.77 \times 10^{-3}$$

**17. Solubility Product** problems refer to difficultly soluble substances and in case the solid remains in contact with its saturated solution,  $[C_1]$ , is constant. Accordingly this factor disappears and the solubility product is simply the product of the ion concentrations,  $[C_2] \times [C_3] = K$  sol. For example: What is the solubility product of lead sulfide, containing 0.86 milligrams per liter, assuming 95 per cent. ionization? The molar concentration is

$$\frac{0.00086}{239} = 0.0000036,$$

and the ion concentration is  $0.0_{\text{5}}36 \times 0.95 = 0.0_{\text{5}}34$ . Therefore, the solubility product constant is  $(0.0_{\text{5}}34)_2 = 1.156 \times 10^{-11}$ . In the solution of a salt like  $\text{Ag}_2\text{S}$ ,  $[\text{C}_2]$  is twice  $[\text{C}_3]$  and consequently  $[\text{C}_2]$  must be squared. If the saturated solution contains 0.10 mg. per liter, and the molecules are 98 per cent. ionized then the concentration of  $[\text{C}_3]$  is  $\frac{0.0001}{248} \times 0.98 = 0.0_{\text{6}}395$  and of  $[\text{C}_2] = 0.0_{\text{6}}79$ . The solubility product constant is, therefore,  $(0.0_{\text{6}}79)^2 \times 0.0_{\text{6}}395 = 2.46 \times 10^{-19}$ .

**18. Common Ion Effect** is produced when two electrolytes, both yielding the same ion, are mixed. The ionization of both electrolytes is, of course, repressed by the common ion, but the effect of the repression is felt only by the electrolyte which supplies a small number of ions to the solution. Thus a decinormal solution of acetic acid yields a concentration of  $\text{H}^+$  of 0.0013 (see par. 16). A similar solution of  $\text{HCl}$  is 90 per cent. ionized, so the hydrogen ion concentration in such a solution is  $0.1 \times 0.9 = 0.09$ . If now a liter of solution is decinormal with respect to both acetic and hydrochloric acids we have the two equilibria  $\text{HC}_2\text{H}_3\text{O}_2 \rightleftharpoons \text{H}^+ + \text{C}_2\text{H}_3\text{O}_2^-$  and  $\text{HCl} \rightleftharpoons \text{H}^+ + \text{Cl}^-$ . Both ionizations are repressed by the presence of the common ion,  $\text{H}^+$ , but since chloride ions are abundant the disappearance of a few will not be noticed. On the other hand, acetate ions are not numerous and if some of these disappear from the solution because of the common ion effect, their loss may be realized. Consequently the noticeable result of the common ion effect is to remove from solution nearly all of those ions from the feeble electrolyte which accompany the common ion. It is evident that the total hydrogen ion concentration in such a solution will be somewhat less than  $0.0013 + 0.09$ , because the ionization of each acid is somewhat repressed by the presence of the common ion. Since the number of hydrogen ions from  $\text{HCl}$  is more than a hundred times the number from  $\text{HC}_2\text{H}_3\text{O}_2$ , it is approximately correct to assume that the total  $\text{H}^+$  present in the mixed solution is the same as would be furnished by the strong



electrolyte alone. This assumption may be made for all cases of the common ion effect, whenever one solute yields relatively few ions and accurate results are not required. Example: What will be the lead ion concentration remaining in solution after  $\text{H}_2\text{SO}_4$  has been added in sufficient excess to yield a tenth normal  $\text{H}_2\text{SO}_4$  solution? A saturated solution of lead sulfate contains 43 milligrams per liter, representing a molar concentration of  $\frac{0.043}{239} = 0.0_{\text{3}}18$ . If the molecules are 90 per cent. ionized then  $[\text{SO}_4^{--}] = 0.0_{\text{3}}18 \times 0.9 = 0.0_{\text{3}}16$  and the solubility product constant is  $(0.0_{\text{3}}16)^2 = 0.0_{\text{7}}256$ . A decinormal solution of  $\text{H}_2\text{SO}_4$  is about 60 per cent. ionized, therefore the sulfate ion concentration from this source is  $0.1 \times 0.6 = 0.06$ . Since the sulfate ion concentration from  $\text{H}_2\text{SO}_4$  is about 400 times that from the  $\text{PbSO}_4$ , the former may be assumed to represent the  $\text{SO}_4^{--}$  concentration in the mixed solution. Since the product  $[\text{Pb}^{++}] \times [\text{SO}_4^{--}]$  cannot exceed  $0.0_{\text{7}}256$ , then the lead ion concentration remaining in solution will be approximately  $\frac{0.0_{\text{7}}256}{0.06} = 4.27 \times 10^{-7}$ .

### CLASS-ROOM EXERCISES IN CHEMISTRY

1. How many different kinds of atoms represented in each of the following substances: (1)  $\text{KClO}_3$ , (2)  $\text{Pb}(\text{NO}_3)_2$ , (3)  $\text{NaC}_2\text{H}_3\text{O}_2$ , (4)  $\text{CaSO}_4$ , (5)  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ , (6)  $\text{Cu}(\text{SO}_4)$ , (7)  $\text{Ca}_3(\text{PO}_4)_2$ , (8)  $\text{NaNO}_3$ , (9)  $\text{Al}_2(\text{SO}_4)_3$ , (10)  $\text{BaCO}_3$ , (11)  $\text{C}_2\text{H}_5\text{OH}$ , (12)  $(\text{NH}_4)_2\text{CO}_3$ ?
2. How many atoms in each of these molecules?
3. Find the molecular weight of each substance.
4. Calculate the per cent. of oxygen in each molecule.
5. Write formulas for the following compounds: (1)  $\text{H:C} = 1:3$ ; (2)  $\text{H:S} = 1:16$ ; (3)  $\text{C:O} = 3:8$ ; (4)  $\text{Fe:S} = 7:4$ ; (5)  $\text{C:S} = 3:16$ ; (6)  $\text{C:H:O} = 12:3:8$ ; (7)  $\text{H:C:O} = 1:6:24$ ; (8)  $\text{H:C:O} = 1:12:32$ ; (9)  $\text{Cl:O} = 35.5:32$ ; (10)  $\text{Fe:S:O} = 7:4:8$ ; (11)  $\text{Fe:S:O} = 7:6:12$ ; (12)  $\text{P:O} = 31:40$ .

6. The composition of certain compounds of copper, mercury and calcium is as follows:

	Per cent., metal	Per cent., other element
(a) Cupric oxide.....	80.0	20.0
(b) Cupric chloride.....	47.3	52.7
(c) Cupric sulfide.....	66.5	33.5
(d) Mercuric oxide.....	92.7	7.3
(e) Mercuric chloride.....	73.9	26.1
(f) Mercuric sulfide.....	86.4	13.4
(g) Calcium oxide.....	71.5	28.5
(h) Calcium chloride.....	36.1	63.9

(1) If the combining weight of oxygen is 8, calculate the combining weights of copper, mercury and calcium. (2) From the combining weights of each of these metals, calculate the combining weights of chlorine and sulfur. (3) What would you expect to be the percentage composition of calcium sulfide? (4) Another oxide of copper, cuprous oxide, contains 88.8 per cent. copper and 11.2 per cent. oxygen. Calculate from this data the combining weight of copper and then the combining weights of chlorine and sulfur in (B) and (C) above. (5) Compare the combining weights formed in (4) with those found in (1) and (2).

7. A compound is composed of 27.3 per cent. carbon and the remainder oxygen. What is the simplest formula for the compound?

8. A compound is made up of 82.35 per cent. nitrogen and 17.65 per cent. hydrogen. Calculate its probable formula.

9. A compound whose molecular weight is 30 contains 80 per cent. carbon and 20 per cent. hydrogen. What is its formula?

10. A compound having a molecular weight of 106.5 is found to contain 21.6 per cent. sodium, 33.3 per cent. chlorine and the remainder oxygen. What is its formula?

11. When 0.14 gram of magnesium ribbon is dissolved in acid, 0.0117 gram of hydrogen is evolved. Find the weight of magnesium which is equivalent to 1 gram of hydrogen.

12. Ten grams of pure zinc, reacting with dilute hydrochloric



acid, yielded 0.3058 grams of hydrogen. Calculate the equivalent of zinc.

13. One gram of magnesium burned in the air gave 1.658 grams of magnesium oxide. What is the equivalent of magnesium?

14. State in words all the information which is conveyed by the symbol Cu; by the formula  $\text{PbSO}_4$ ; by the equation  $\text{KClO}_3 = \text{KCl} + 3\text{O}$ .

15. What weight of oxygen will combine with 1 gram each of sulfur, copper and mercury?

16. What weight of sulfur will combine with 10 grams of Hg?

17. If 1 gram of sulfur and 4 grams of copper are made to enter into combination, which element will be found to be in excess? How much?

18. How much silver can be obtained from 1 ton of an ore which contains 5 per cent. of the compound  $\text{Ag}_2\text{S}$ ?

19. Oxygen is passed over 2.675 grams of heated magnesium and the resulting oxide weighs 4.45 grams. Find the combining weight of the metal.

20. Three grams of sulfur when burned in oxygen yield 6 grams of an oxide. Calculate its formula.

21. Calculate the combining weight of copper from the following:

Weight of empty boat 15.593.

Weight of boat and copper 16.285.

Weight of boat and copper oxide 16.459.

22. On analysis 6 grams of a compound of copper and chlorine were found to contain 3.84 grams of copper. What is the formula of the compound?

23. Ten grams of iron, when burned in oxygen, yield 13.81 grams of an oxide. Calculate its formula.

24. What weight of oxygen can be obtained from 100 grams of mercuric oxide?

25. What volume of oxygen is evolved when 21.6 grams of mercuric oxide is completely decomposed?

26. A quantity of mercuric oxide is decomposed giving 11.2 liters of oxygen. How many grams of mercury will be freed at the same time?

27. What volume of oxygen will be used up in forming 150 grams of mercuric oxide by heating mercury and oxygen?

28. What weight of potassium chlorate is required to yield 60 grams of oxygen?

29. A tank holds 25 liters. How much potassium chlorate should be heated in order to fill it with oxygen allowing 10 per cent. for waste?

30. A quantity of potassium chlorate is heated yielding 10 liters of oxygen. How much potassium chloride is formed?

31. When sodium peroxide reacts with water, what per cent. of the oxygen is liberated?

32. How much sodium peroxide is needed to furnish 10 liters of oxygen?

33. How much water is required to react with 50 grams sodium peroxide?

34. How much sodium hydroxide is formed when 780 grams of sodium peroxide react with water?

35. A quantity of sodium peroxide reacts with water yielding 100 liters of oxygen. How much sodium hydroxide is formed? How much water is used?

36. What weight of oxygen is needed to burn 1 ton of pure carbon?

37. What weight of carbon dioxide should be formed for every ton of coal burned, assuming 90 per cent. carbon?

38. How many liters of oxygen are required to burn completely 1 ton of coal, containing 90 per cent. carbon?

39. Which requires more oxygen for complete burning, 1 pound of charcoal or 1 pound of sulfur? What is the ratio between these amounts of oxygen?

40. What weight of phosphorus may be burned in 10 liters of oxygen?

41. How much phosphorus pentoxide is formed when 62 pounds of phosphorus are burned?

42. What is the percentage composition of phosphorus pentoxide? Of magnetic oxide of iron?

43. When iron burns in oxygen in what ratio do these elements combine?

44. Which requires the larger volume of oxygen for combustion, 1 pound of phosphorus or 1 pound of iron? What is the ratio between the two volumes?

45. How much carbon is there in a gram atom? A gram-molecule of carbon dioxide? A gram-molecule of sugar ( $C_{12}H_{22}O_{11}$ )?

46. How much sulfur must be burned to give a gram-molecule of sulfur dioxide?

47. What volume of oxygen is needed to form a gram-molecule of phosphorus pentoxide?

48. How many calories of heat are liberated on burning 48 grams of carbon? Sixteen grams of sulfur? One hundred grams of mercury?

49. If the burning of 9 grams of phosphorus liberates 53,400 calories, calculate the heat of combustion of phosphorus.

50. In attempting to determine the heat of combustion of carbon a student burned 1 gram and detected the liberation of 7676 calories of heat. Determine his percentage error.

51. How many calories of heat are required to raise 10 grams of the following substances 10 degrees: (1) water, (2) aluminium (specific heat = 0.2055), (3) copper (specific heat = 0.093), (4) iron (specific heat = 0.19)?

52. Find the weight of 100 cc. of water; of nitric acid (sp. gr. 1.5); of glycerine (sp. gr. 1.26); of ammonia (sp. gr. 0.9); and of iron (sp. gr. 7.85).

53. Find the volume of 150 k. of water; of sulfuric acid (sp. gr. 1.84); of hydrofluoric acid (sp. gr. 1.07); of lead (sp. gr. 11.34).

54. A block measuring  $5 \times 10 \times 20$  cm. weighs 3.25 k. Find its specific gravity.

55. A rectangular vessel is 4 m. long, 50 cm. wide and 500

mm. deep. How many kilograms of glycerine of specific gravity 1.25 will it hold?

56. What weight of oxygen is needed to fill a rectangular receptacle 2 m. long, 10 cm. wide and 100 mm. deep, at  $0^{\circ}$  and 760 mm.?

57. Compare the cost of the raw material needed to produce a liter of oxygen from  $\text{HgO}$ , costing one-third of a cent per gram, from  $\text{KClO}_3$  costing 35 cents a kilogram and from  $\text{Na}_2\text{O}_2$  costing 15 cents for 100 grams.

58. Calculate the volume under standard conditions in each of the following cases:

- (a) volume 200 cc., temp.  $20^{\circ}\text{C}$ ., barometer reading 745 mm.
- (b) volume 100 cc., temp.  $17^{\circ}\text{C}$ ., barometer reading 740 mm.
- (c) volume 300 cc., temp.  $-10^{\circ}\text{C}$ ., barometer reading 755 mm.
- (d) volume 100 cc., temp.  $100^{\circ}\text{C}$ ., barometer reading 100 mm.

59. A quantity of gas measures 125 cc. at  $17^{\circ}\text{C}$ . and 735 mm. Find the volume it will occupy at  $20^{\circ}\text{C}$ . and 750 mm.

60. A certain gas measured over water at  $20^{\circ}$  and 735 mm. occupies 140 cc. What volume will the dried gas have over mercury at  $-10^{\circ}$  and 770 mm.?

61. When measured over mercury at  $12^{\circ}$  and 725 mm. a gas has a volume of 175 cc. Find its volume when measured over water at  $23^{\circ}$  and 750 mm.

62. What volume will 1.429 gram of oxygen occupy at  $24^{\circ}\text{C}$ . and 740 mm. pressure?

63. What volume will be occupied by the oxygen obtainable from 100 grams  $\text{KClO}_3$ , in a room whose temperature is  $21^{\circ}\text{C}$ . and atmospheric pressure is 742 mm.?

64. Find the weight of one liter of oxygen at  $18^{\circ}$  and 740 mm.

65. A given volume of gas at  $17^{\circ}\text{C}$ . exerts a pressure of 760 mm. What pressure will it exert if the volume is kept constant and the temperature raised to  $70^{\circ}\text{C}$ .?

66. What volume of oxygen, measured at  $15^{\circ}$  and 750 mm., will be required to burn 100 grams of carbon?

67. What weight of  $\text{HgO}$  should be used in order to obtain enough oxygen to fill a bottle holding 450 cc., the temperature of the room being  $15^{\circ}\text{C}$ . and the barometric reading 720 mm.?

68. Oxygen is admitted to a eudiometer which is filled with mercury, until it contains 35 cc. The mercury within the tube is 320 mm. above that on the outside, the barometer reads 750 mm. and the temperature is  $22^{\circ}$ . Find the volume of oxygen under standard conditions.

69. A eudiometer tube contains 77 cc. of oxygen when the mercury within the tube is 27 cm. above the mercury on the outside, and the temperature is  $20^{\circ}\text{C}$ . The eudiometer is lowered until the inner level of mercury is 5 cm. below the level on the outside, and the temperature has dropped to  $17^{\circ}$ . The barometer has remained constant at 745 mm. Find the new volume of the oxygen.

70. A flask whose capacity is 136 cc. weighs 14.2782 grams when filled with air at a temperature of  $12^{\circ}$  and pressure of 750 mm. The air is pumped out until the pressure within is 20 mm., when the weight is found to be 14.1166, the temperature remaining unchanged. Find the weight of a liter of air.

71. A bulb with a capacity of 340 cc. weighs 21.784 grams when full of air at  $20^{\circ}$  and 744 mm. It is filled with another gas at the same temperature and pressure when it weighs 22.923. Find the weight of one liter of the gas.

72. In an attempt to determine the weight of a liter of chlorine 225 cc. of the gas are found to weigh 0.3945 grams. At the time the volume of the gas is determined the temperature is  $17^{\circ}$  and the pressure 720 mm. Calculate the per cent. of error.

73. What weight of hydrogen can be set free by the action of 10 grams of zinc upon  $\text{H}_2\text{SO}_4$ ? Upon  $\text{HCl}$ ?

74. What weight of hydrogen can be set free from  $\text{HCl}$  by 10 grams each of zinc, sodium, iron and aluminium?

75. What volume of hydrogen can be obtained by the action of 5.6 grams of iron upon steam? Upon  $\text{HCl}$ ?



76. How much zinc sulfate is formed when 10 liters of hydrogen are liberated by the action of zinc and sulfuric acid?

77. Steam is passed over iron filings until 23 grams of magnetic oxide are formed. How much hydrogen is liberated?

78. What volume of hydrogen will be liberated by the action of 16 grams of sodium on water? How much sodium hydroxide is formed?

79. What volume of hydrogen will result from the electrolysis of 5 grams of water, the temperature of the room being  $21^{\circ}\text{C}$ . and the pressure being 737 mm.?

80. A balloon weighs 20 kilograms. How many liters of hydrogen must it contain in order to be able to lift a man weighing 80 kilograms? (Assume standard temperature and pressure.)

81. What weight of copper oxide may be reduced by 10 liters of hydrogen?

82. A stream of hydrogen is passed through a hot tube containing copper oxide until it has lost 1.25 grams. What weight of copper and of steam has been formed?

83. How many cubic centimeters of water are formed when 10 grams of hydrogen are burned?

84. Hydrogen and chlorine are diffused through a porous wall. It requires as much time for 53 cubic centimeters of chlorine to diffuse as for 316 cc. of hydrogen. Determine the density of chlorine compared to hydrogen.

85. Calculate the percentage of hydrogen in marsh gas,  $\text{CH}_4$ , acetylene,  $\text{C}_2\text{H}_2$ , and benzene,  $\text{C}_6\text{H}_6$ .

86. If hydrogen could be readily obtained from benzene,  $\text{C}_6\text{H}_6$ , what volume could be obtained from 10 grams?

87. Write the formulas for the sodium, calcium, and chromium salts of  $\text{HNO}_3$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{H}_2\text{S}$ .

88. Indicate the valence of each metal and each non-metallic element or radical in the following: (a)  $\text{Na}_2\text{SO}_4$ , (b)  $\text{Pb}(\text{NO}_3)_2$ , (c)  $\text{CuCO}_3$ , (d)  $\text{CaCl}_2$ , (e)  $\text{Al}_2\text{S}_3$ , (f)  $\text{CrO}_3$ , (g)  $\text{CO}_2$ , (h)  $\text{Sn}_3(\text{PO}_4)_4$ .

89. Using the same valences as in the preceding problem,

write the formulas for sodium carbonate, lead chloride, copper sulfate, calcium sulfide, aluminium nitrate, stannic chloride, calcium phosphate.

90. If 23 milligrams of sodium liberate 11 cc. of hydrogen, calculate the hydrogen equivalent of sodium, considering that one liter of the gas weighs 0.09 g.

91. Twenty-four milligrams of magnesium set free 22 cc. of hydrogen. What volume of hydrogen will be liberated by 24 grams of magnesium?

92. What weight of zinc will be needed to replace the hydrogen in 98 grams of sulfuric acid?

93. What weight of sodium will replace 100 grams of hydrogen when it reacts with  $\text{HCl}$ ? With  $\text{H}_2\text{O}$ ?

94. If 5 cc. of oxygen combines with 9.85 cc. of hydrogen forming 9.9 cc. of steam, calculate the simplest ratio of volumes of oxygen, hydrogen and steam.

95. Oxygen measuring 9.4 cc. was admitted to a eudiometer, when the mercury stood 564 mm. above the level in the dish. Then hydrogen was admitted till the mixture measured 26.5 and the height of the mercury was 468 mm. After exploding the mixture, the residue measured 13.7 cc. and the height of the mercury was 546 mm. When steam was passed around the eudiometer the volume within was 26.2 cc. and the height of the mercury was 476 mm. The temperature of the room remained constant at  $27^\circ$  and the barometer reading was 743. Determine the ratio  $\text{H} : \text{O} : \text{H}_2\text{O}$ .

96. In determining the composition of water by the use of copper oxide 3.7256 grams of hydrogen united with 29.5789 grams of oxygen. Calculate the atomic weight of hydrogen on the basis  $\text{O} = 16$ .

97. How many calories of heat are given off when 10 grams of water at  $20^\circ \text{C}$ . are changed to ice at  $0^\circ$ ?

98. How many grams of carbon must be burned in order to melt 1 kilogram of ice and change the water into steam, assuming that half the heat liberated by the burning carbon is lost?



99. How many grams of hydrogen must be burned in oxygen in order to change 1 kilogram of boiling water into steam?

100. How many grams of water may be heated from  $18^{\circ}$  to  $100^{\circ}$  by the heat used in melting a kilogram of ice?

101. Find the specific gravity of a solid 10 cubic centimeters of which weigh 78 grams.

102. A substance has a specific gravity of 8.5. Find the weight of 25 cubic centimeters.

103. If 100 grams of water are saturated with  $\text{NH}_4\text{Cl}$  at  $100^{\circ}$  and then allowed to cool to  $20^{\circ}$ , what weight of solute will crystallize out? If the solute is  $\text{NaCl}$ ? If it is  $\text{KNO}_3$ ?

104. How many grams of carbon must be burned to change 1 kilogram of water at  $20^{\circ}$  to steam at  $100^{\circ}$ ?

105. How many grams of carbon must be burned to melt 1 kilogram of ice? How many grams of hydrogen?

106. How many calories of heat are required to raise the temperature of a kilogram of a liquid from  $15^{\circ}$  to  $65^{\circ}$  if the specific heat is 0.5?

107. How much anhydrous  $\text{Na}_2\text{SO}_4$  is there in a kilogram of crystalline sodium sulfate?

108. What weight of copper is represented in a ton of blue vitriol?

109. How much 3-per cent. solution of hydrogen peroxide can be made from 50 grams of barium peroxide? From 50 grams sodium peroxide?

110. How many cubic centimeters of a 3-per cent. solution of hydrogen peroxide are needed to oxidize 10 grams of  $\text{PbS}$ , assuming the solution to have a specific gravity of 1.01?

111. What is the vapor pressure of hydrogen peroxide at  $69.2^{\circ}$ ?

112. If 10 cc. of hydrogen peroxide solution liberate 30 cc. of oxygen when decomposed without the aid of other oxidizing agents, what is the strength of the peroxide?

113. If the decomposition of 1 cc. of hydrogen peroxide solution with acidified  $\text{KMnO}_4$  yields 18 cc. of oxygen, what is the strength of the solution?

**114.** When hydrogen peroxide solution of specific gravity 1.01 is decomposed in contact with  $\text{KMnO}_4$  it yields ten times its volume of oxygen. Find the per cent. by weight of  $\text{H}_2\text{O}_2$  in the solution.

**115.** The density of liquid hydrogen is 0.07. What will 10 cubic centimeters of the liquid weigh? When this liquid is changed to a gas what volume will it occupy at  $20^\circ$  and 740 mm?

**116.** When 0.5 gram  $\text{KClO}_3$  and 0.7 gram  $\text{KClO}_4$  are heated in separate tubes until all the oxygen is expelled the residues weigh 0.3 gram and 0.3766 gram respectively. Calculate the amount of oxygen which is in combination with 1 gram  $\text{KCl}$  in both cases. How does this illustrate the Law of Multiple Proportion?

**117.** Three oxides of nitrogen show the following percentage composition:

	No. 1	No. 2	No. 3
Nitrogen . . . . .	63.65	25.94	46.68
Oxygen . . . . .	36.35	74.06	53.32

Show how these illustrate the Law of Multiple Proportion.

**118.** Two oxides of phosphorus contain, respectively, 56.34 and 43.63 per cent. of oxygen. Show how these compounds illustrate the Law of Multiple Proportion.

**119.** Find the weight of 1 liter of the following gases under standard condition:  $\text{HCl}$ ,  $\text{HCN}$ ,  $\text{CO}_2$ ,  $\text{NH}_3$ .

**120.** Find the density of the same gases as compared to air.

**121.** If a liter of a gas weighs 2.858 grams, find its molecular weight. If the gas contains 50 per cent. sulfur and 50 per cent. oxygen determine the formula.

**122.** A gas has the formula  $\text{C}_2\text{H}_2$ . What does 1 liter weigh?

**123.** How many liters of sulfur dioxide will be formed when 64 grams of sulfur are burned? How many liters of oxygen are used?

**124.** The molecular weight of a gas is 34. Find the weight of a liter at  $17^\circ$  and 750 mm.

125. If 125 cc. of ozone weigh 0.2679, calculate the formula.

126. A gas has a density 2.213 compared with air. It is composed of equal parts by weight of sulfur and oxygen. Find the molecular weight and the formula.

127. A certain gas is composed of 20 per cent. hydrogen and 80 per cent. carbon. Find the formula and the density compared with air, if 200 cc. weigh 0.2684 gram.

128. A gas contains two elements, one of which is hydrogen which composes 3.85 per cent. of the compound. If 100 cc. of the gas weighs 0.3485 gram determine the formula of the gas and the valence of the unknown element X.

129. The density of a gas compared with air is 0.968. It contains 14.3 per cent. of hydrogen combined with carbon. Find the formula.

130. The density of a gas referred to air is 1.176. Find the weight of one liter.

131. Calculate the weight of one liter of a gas whose formula is HCN.

132. What volume of chlorine results from the oxidation of a kilogram of HCl, if  $\text{MnO}_2$  is used? If  $\text{KMnO}_4$ ?

133. What weight of  $\text{MnO}_2$  is required for the oxidation of 10 liters of HCl? What weight of  $\text{KMnO}_4$ ?

134. What weight of  $\text{MnCl}_2$  results when 10 liters of chlorine are prepared by oxidizing HCl with  $\text{MnO}_2$ ? With  $\text{KMnO}_4$ ?

135. Compare the cost of the raw material for the preparation of a liter of chlorine if HCl gas costs one mill per liter,  $\text{MnO}_2$  costs 30 cents per kilogram,  $\text{KMnO}_4$  costs 6 cents per 100 grams.

136. What weight of hydrogen will be liberated during the liberation of 10 liters of chlorine by electrolysis?

137. What volume of chlorine will combine with 25 grams of sodium? Of Cu?

138. What volume of HCl results from burning 71 grams of chlorine in hydrogen?

139. What weight of carbon is liberated when 250 cc. of chlorine react with turpentine? What volume of HCl results?

**140.** What volume of chlorine is required to form 25 grams of  $\text{Cl}_2 \cdot 8\text{H}_2\text{O}$ ?

**141.** In Deacon's process what volume of oxygen is needed to oxidize 40 liters of  $\text{HCl}$ ? What volume of air?

**142.** In Deacon's process if 80 per cent. oxidation is secured what gases issue from the reaction chamber? What per cent. of the resulting gases is chlorine, if oxygen is used? If air, assuming 20 per cent. oxygen?

**143.** In Deacon's process how does the sum of the volumes of  $\text{HCl}$  and oxygen compare with the sum of the volumes of chlorine and steam, assuming complete oxidation? If 80 per cent. oxidation is secured compare the total volume of gases used with the volume of the gaseous products.

**144.** What volume of  $\text{HCl}$  will result from burning 35.5 grams of chlorine in hydrogen?

**145.** What volume of  $\text{HCl}$  may be obtained from 100 gram of  $\text{NaCl}$  if  $\text{NaHSO}_4$  is formed? If  $\text{Na}_2\text{SO}_4$ ?

**146.** What is the raw material cost per kilogram of  $\text{HCl}$  if salt costs 12 cents per kilogram and sulfuric acid costs 7 cents per kilogram?

**147.** What volume of  $\text{HCl}$  gas is required to dissolve 65 grams of zinc?

**148.** With what weight of  $\text{Ca(OH)}_2$  will 44.8 liters of  $\text{HCl}$  gas react?

**149.** What volume of chlorine is required to prepare 100 kilograms of bleaching powder?

**150.** When chlorine is passed into a hot concentrated solution of potassium hydroxide,  $\text{KClO}_3$  is finally formed. What per cent. of the chlorine used is represented in the  $\text{KClO}_3$ ?

**151.** What volume of chlorine is needed to prepare 100 liters of a 1-per cent. solution of sodium hypochlorite, assuming the latter to have a specific gravity of 1.

**152.** If chlorine is passed into a solution of  $\text{KOH}$  until crystals of  $\text{KClO}_3$  appear, what volume of chlorine is needed to produce 10 gram of  $\text{KClO}_3$ ?

**153.** What weight of oxygen is combined with 1 gram of

KCl in the compound  $\text{KClO}_3$ ? With 1 gram of KCl in  $\text{KClO}_4$ ? Compare the two quantities of oxygen and state the law illustrated.

**154.** What volume of liquid bromine is obtainable from 1000 kilograms of brine which contains 2 per cent. KBr, assuming the brine to have a specific gravity of 1.05, and the bromine 3.18?

**155.** What volume of liquid bromine will be displaced from a solution of KBr by the addition of 25 liters of chlorine?

**156.** What volume will 80 grams of bromine occupy at  $228^\circ$ ?

**157.** How many cubic centimeters of liquid bromine in a 1-pound bottle?

**158.** What volume of liquid bromine is needed to form 10 liters of HBr?

**159.** What weight of phosphorus will combine with 10 cc. of liquid bromine to form phosphorus tribromide? What volume of HBr can be obtained from the phosphorus bromide formed?

**160.** How many cubic centimeters of liquid bromine are needed to prepare 1 liter of a 10-per cent. solution of sodium hypobromite?

**161.** If 1 pound of bromine is added to NaOH to form sodium bromate, what weight of the latter may be expected?

**162.** If a ton of kelp yields 1.8 kilograms of iodine, calculate the per cent. of iodine in the kelp.

**163.** How many grams of iodine may be expected from a ton of crude sodium nitrate which contains 0.2 per cent. of  $\text{NaIO}_3$ ?

**164.** If 1 kilogram of iodine is recovered from a ton of crude sodium nitrate which contains 0.2 per cent.  $\text{NaIO}_3$ , what per cent. of iodine is lost in the recovery process?

**165.** What weight of iodine is needed to prepare 1000 cc. of hydriodic acid solution of specific gravity 1.70, containing 57 per cent. of the acid?



**166.** What weight of water is needed to hydrolyze 15 grams of phosphorus triiodide? What volume of hydrogen iodide results?

**167.** What weight of calcium fluoride is needed to prepare a liter of hydrofluoric acid solution, of specific gravity 1.117 containing 35 per cent. acid? How much  $\text{H}_2\text{SO}_4$ ?

**168.** Calculate the weight of 1 liter of gases of the following formulas:  $\text{HF}$ ,  $\text{H}_2\text{F}_2$ ,  $\text{SiF}_4$ .

**169.** Calculate the percentage of fluorine in  $\text{Na}_3\text{AlF}_6$ .

**170.** What volume of  $\text{S}_2$  molecules are needed to form 1 gram-molecule of  $\text{S}_8$ ?

**171.** At a certain temperature a liter of sulfur vapor is found to weigh 8.57 grams. Assuming that it is a mixture of  $\text{S}_2$  and  $\text{S}_8$  molecules, calculate the per cent. of each.

**172.** If the density of sulfur vapor is 6.6, what would be the formula for the molecules present, assuming that they are all alike?

**173.** How much sulfuric acid is needed in the preparation of sufficient  $\text{H}_2\text{S}$  to fill a cylindrical gasometer 2 meters in diameter and 1.5 meters high, if the gas is kept under a pressure of two atmospheres?

**174.** A laboratory uses 500 liters of  $\text{H}_2\text{S}$  per day. Calculate the weight of  $\text{FeS}$  used each day in supplying the gas, assuming the average temperature to be  $20^\circ$  and the pressure 735 mm.

**175.** What volume of hydrogen is needed to combine directly with 64 grams of sulfur? What volume of  $\text{H}_2\text{S}$  is formed?

**176.** What volume of hydrogen sulfide will be required to precipitate all the arsenic from a solution containing 18.15 grams of arsenic trichloride?

**177.** If equimolecular solutions of sugar,  $\text{HCl}$  and  $\text{H}_2\text{S}$  have freezing points  $-0.184^\circ$ ,  $-0.355^\circ$  and  $-0.196^\circ$  respectively, calculate the per cent. of ionization in the  $\text{HCl}$  and  $\text{H}_2\text{S}$  solutions.

**178.** Assuming that 1 mole of an un-ionized solute in 1 liter of water lowers the freezing point of the solvent  $1.84^\circ$ ,

calculate the freezing point of a solution of methyl acetate,  $\text{CH}_3\text{C}_2\text{H}_3\text{O}_2$ , containing 6.5 grams in 250 cc. water.

**179.** If 1 gram of a non-electrolyte dissolved in 200 cc. of water lowers the freezing point of the water  $0.2^\circ$ , what is the molecular weight of the solute?

**180.** Disregarding any chemical reaction, what will be the freezing point of a solution made up by dissolving 5 grams of chlorine in a liter of water?

**181.** What weight of  $\text{C}_2\text{H}_6\text{O}$  must be dissolved in a liter of water to give a freezing point of  $-0.1^\circ$ ?

**182.** What volume of  $\text{H}_2\text{S}$  is required for the reduction of 63.5 grams of iodine?

**183.** What weight of iodine is reduced by  $\text{H}_2\text{S}$  when 64 grams of sulfur are precipitated?

**184.** What weight of potassium dichromate will be reduced by 134.4 liters of  $\text{H}_2\text{S}$ ?

**185.** What volume of  $\text{H}_2\text{S}$  gas is required to reduce 25 grams of  $\text{KMnO}_4$ ?

**186.** What volume of  $\text{H}_2\text{S}$  would we expect to be oxidized by a gram-molecule of  $\text{CaMnO}_3$ ?

**187.** What weight of sulfur is required to prepare 11.2 liters of sulfur dioxide? What weight of  $\text{FeS}_2$ ?

**188.** Compare the raw material cost of preparing a gram-molecular volume of  $\text{SO}_2$  from four sources when sulfur is selling for 10 cents a pound; pyrites at \$50 per ton; sodium acid sulfite 45 cents per kilogram; copper turnings at 40 cents per pound and sulfuric acid at 10 cents a pound.

**189.** If the density of an oxide of sulfur is 2.26 compared to air, and it is found to be composed of equal parts of sulfur and oxygen, determine the formula.

**190.** How would you proceed to prove that an oxide of sulfur has the formula  $\text{SO}_2$  and not  $\text{S}_2\text{O}_4$ ?

**191.** How many grams of sulfur must be burned to saturate a liter of water with  $\text{SO}_2$ ?

**192.** How many liters of  $\text{SO}_2$  must be used in the preparation of 12.6 grams of sodium sulfite?



193. What amount of sulfurous acid is oxidized to sulfuric acid by a gram-molecule of  $\text{KMnO}_4$ ?

194. Compare the volumes of  $\text{SO}_2$  required in the preparation of a gram-molecule of sodium sulfite and of sodium acid sulfite.

195. What volume of oxygen combines with 30 liters of  $\text{SO}_2$  in the contact process?

196. What volume of hydrogen chloride gas is required to form a liter of solution whose specific gravity is 1.2 containing 39.11 per cent.  $\text{HCl}$ ?

197. What weight of sodium hydroxide will be neutralized by 100 cc. of a solution of sulfuric acid, density 1.1 containing 14.35 per cent. pure acid?

198. What weight of magnesium may be dissolved in a liter of hydrochloric acid solution which is 1.25 normal?

199. What weight of potassium carbonate may be neutralized by 200 cc. of a solution of sulfuric acid which is 1.75 normal?

200. One cubic centimeter of a solution of nitric acid neutralizes 1.55 cc. of a normal solution of sodium hydroxide. How many cc. of the acid solution are required to dissolve 100 grams of zinc oxide?

201. How many cubic centimeters of a normal solution of silver nitrate must be added to precipitate the chlorine from a solution containing 10 grams of  $\text{ZnCl}_2$ ?

202. Concentrated sulfuric acid with a specific gravity 1.83 contains 92.1 per cent. pure acid. Calculate the normal strength represented.

203. Calculate the normality of a solution of phosphoric acid which contains 150 grams per liter.

204. What volume of ammonia  $\text{NH}_3$  is needed to neutralize a liter of 1.5 normal sulfuric acid?

205. What volume of  $\text{SO}_2$  must be supplied to prepare a liter of 0.6 normal sulfurous acid?

206. What volume of  $\text{CO}_2$  is liberated when a liter of 3.5 normal sulfuric acid is neutralized by  $\text{Na}_2\text{CO}_3$ ?

207. What volume of  $\text{SO}_2$  is used in preparing a liter of tenth normal  $\text{Na}_2\text{SO}_3$ ?

208. What volume of ammonia  $\text{NH}_3$  is required to neutralize 400 cc. of 1.35 normal  $\text{HCl}$ ?

209. A 10-per cent. solution of  $\text{MnCl}_2$  has a density of 1.09. Calculate the concentration in terms of the normal solution.

210. A solution of sodium chloride containing 11 per cent. of the solute has a density of 1.08. Calculate the formular strength of the solution.

211. A solution of phosphoric acid contains 25 per cent. of the pure acid and has a specific gravity of 1.15. Calculate the normal strength.

212. Ten cubic centimeters of dilute sulfuric are neutralized by 12 cc. of  $\text{KOH}$  and yield 0.174 gram of  $\text{K}_2\text{SO}_4$ . Calculate the normal strength of the acid and of the base.

213. How many milligrams of sodium hydroxide are neutralized by 1 cc. of 0.7 normal nitric acid?

214. What weight of sodium thiosulphate may be prepared from 100 grams of sodium sulfite?

215. What volume of  $\text{SO}_2$  is liberated by acidifying a liter of a solution of  $\text{Na}_2\text{S}_2\text{O}_3$  which is twice normal?

216. What volume of pure nitrogen is obtainable from a mixture of one gram molecular weights of  $\text{NaNO}_2$  and  $\text{NH}_4\text{Cl}$ ?

217. What will be the cost of the raw material needed to prepare 100 liters of pure nitrogen when  $\text{NH}_4\text{Cl}$  is selling for 9 cents per 100 grams and  $\text{NaNO}_3$  for 80 cents per kilogram?

218. Nitrogen and hydrogen are mixed in the proportions needed to form  $\text{NH}_3$ . If the gases are completely combined, how does the volume of ammonia compare with the volume of the mixed gases? If 22.4 liters of  $\text{NH}_3$  are formed, what volumes of nitrogen and hydrogen have been used?

219. What volume of ammonia gas is required to exactly neutralize a liter of normal  $\text{HCl}$  solution? A liter of normal  $\text{H}_2\text{SO}_4$  solution?

220. What volume of ammonia gas will be needed to exactly neutralize a G. M. V. of  $\text{H}_2\text{S}$  gas? Of  $\text{HCl}$  gas?

221. What volume of gaseous ammonia is required to neutralize 1 liter of 1.5 N  $\text{H}_3\text{PO}_4$ ?

222. What weight of  $\text{Ca}(\text{OH})_2$  reacting with  $\text{NH}_4\text{Cl}$  is required to give 22.4 liters of  $\text{NH}_3$  gas?

223. How much  $(\text{NH}_4)_2\text{SO}_4$  is needed for the preparation of 100 liters of  $\text{NH}_3$ ?

224. What volume of ammonia gas will be obtained from 50 grams of  $\text{NH}_4\text{NO}_3$ , at a temperature of  $20^\circ$  and pressure of 730 mm?

225. What is the weight of ammonia in a liter of solution whose specific gravity is 0.9? What volume of water is present in this solution? What volume will the ammonia gas occupy under standard conditions?

226. If the heat of vaporization of liquid ammonia is 330 calories per kilogram, what volume of liquid ammonia must be evaporated in order to freeze 1 kilogram of water at  $0^\circ$ ?

227. How much sulfuric acid is needed to prepare 100 lbs. of nitric acid?

228. How much nitric acid can be prepared from 30 grams of magnesium nitrate?

229. How much sodium nitrate is needed to prepare 100 lbs. of nitric acid?

230. Calculate the cost of the raw materials needed to make a pound of nitric acid when sulfuric acid costs 8 cents per pound and Chile saltpeter sells for \$60 per ton.

231. How much nitric acid will react with a liter of a 15-per cent. solution of ammonia, which has a specific gravity of 0.942?

232. What volume of 6N  $\text{H}_2\text{SO}_4$  must be used to prepare 2.5 liters of  $\text{HNO}_3$ , of specific gravity 1.42, containing 70 per cent.  $\text{HNO}_3$ ?

233. What weight of ferrous sulfate will be oxidized in the presence of dilute sulfuric acid to the ferric salt by 100 c.c. of  $\text{N}/2 \text{HNO}_3$ ?

234. Compare the per cent. of oxygen in  $\text{N}_2\text{O}$  and  $\text{NO}$  and their behavior toward combustion. Explain.

**235.** What volume of nitric oxide will be produced when 100 grams of copper are dissolved in nitric acid, assuming that no other gas is formed?

**236.** Express in simple numerical values the ratio between the amounts of oxygen in the oxides of nitrogen. How do these values illustrate the Law of Multiple Proportion?

**237.** With what volume of oxygen will 5 liters of nitric oxide combine? What volume of the dioxide will result?

**238.** If nitrogen and oxygen could be combined directly to form the various oxides, what volume changes would be expected when  $N_2O$ ,  $NO$ ,  $N_2O_3$  respectively, are made?

**239.** How much ammonium nitrate is theoretically possible when dilute nitric acid reacts with 25 grams of zinc?

**240.** Determine the specific gravity of the gases  $N_2O$ ,  $NO$ ,  $N_2O_3$  and  $NO_2$  compared with air.

**241.** Assuming an atmospheric pressure of 760 mm. and 75.5 per cent. by weight of nitrogen in the air, calculate the weight of  $HNO_3$  which could be produced from the nitrogen above one square meter of the earth's surface.

**242.** When air reacts with  $NO$  to form  $NO_2$  what volume change takes place?

**243.** What per cent. of  $NO_2$  and of  $N_2O_4$  is present in a mixture 22.4 liters of which weighs 80 grams? Sixty-nine grams?

**244.** At  $26^\circ$  a liter of nitrogen tetroxide weighs 3.42 grams. What per cent. of the  $N_2O_4$  molecules have been converted to  $NO_2$ ?

**245.** At  $1000^\circ$  bromine vapor is 76.94 times as heavy as hydrogen. What per cent. of the diatomic molecules have dissociated into monatomic molecules?

**246.** If 0.05 per cent. by weight of the atmosphere is carbon dioxide, calculate the amount of this gas over each square meter of the earth's surface, when the barometer stands at 760 mm.

**247.** Calculate the volumes of oxygen, of nitrogen and of carbon dioxide in a room 5 m. square and 3 m. high.

**248.** One hundred liters of moist air were dried by passing

through concentrated sulfuric acid, which increased in weight 5.25 grams. What per cent. of moisture by volume was present in the air?

**249.** What would a liter of pure water vapor weigh if it could be obtained at  $0^{\circ}$  and 760 mm.? What is its specific gravity compared with dry air?

**250.** Compare the weight of 10 liters of dry air with the same volume of air containing 1.2 per cent. moisture by volume.

**251.** If all the oxygen in the air were combined with carbon forming carbon dioxide, what would be the per cent. of the latter by volume?

**252.** Calculate the total weight of moisture in a room  $10 \times 10 \times 4$  m. when the moisture is 5 per cent. by volume. What volume of liquid would this make if it were condensed?

**253.** If a person exhales 20 liters of  $\text{CO}_2$  per hour how long would be required to raise the percentage of  $\text{CO}_2$  to 0.07 by volume in a closed room  $5 \times 4 \times 3$  meters?

**254.** If a gas jet burns illuminating gas at a rate equivalent to 60 liters of carbon monoxide per hour, how long will be required to raise the carbon dioxide content of a room  $5 \times 4 \times 3$  meters to 0.07 per cent.?

**255.** A balloon filled with helium would have what lifting power compared with the same balloon filled with hydrogen?

**256.** How much phosphorus could be recovered from a ton of bone ash if it contains 70 per cent.  $\text{Ca}_3(\text{PO}_4)_2$ ?

**257.** What is the per cent. of phosphorus in the mineral apatite  $\text{Ca}_5(\text{PO}_4)_3\text{F}$ ?

**258.** How much potassium hydroxide is required in the preparation of 2.7 grams of phosphine? What volume will this amount of phosphine occupy under standard conditions?

**259.** On igniting a sample of  $\text{MgNH}_4\text{PO}_4$ , there was obtained 1.4250 grams of magnesium pyrophosphate. How much magnesium ammonium phosphate was ignited?

**260.** A sample of phosphoric acid was precipitated as magnesium ammonium phosphate and ignited to the magnesium



pyrophosphate. If 0.725 grams of the latter were obtained, how much phosphoric acid was present in the original solution?

**261.** What methods are available for starting a fire without the use of phosphorus or its compounds?

**262.** A man weighs 150 lb., his bones comprising 6 per cent. of his weight; if the bones contain 40 per cent.  $\text{Ca}_3(\text{PO}_4)_2$ , what amount of phosphorus could be extracted?

**263.** Determine the density of arsine compared with air.

**264.** If metallic bismuth expands on solidifying, will solid bismuth sink or float in a dish of molten bismuth?

**265.** In the direct union of carbon and hydrogen forming methane, will an increase of pressure aid or hinder the combination of the elements?

**266.** What volume of methane may be expected from heating 12 grams of sodium acetate with sodium hydroxide?

**267.** With what volume of air should methane be mixed in order to secure complete combustion? Ethane? Acetylene?

**268.** What volume of air, measured at  $20^\circ$  and 740 mm. will be required to burn 20 grams of carbon to the dioxide?

**269.** Fifty cc. of oxygen were added to an equal volume of a mixture of methane and inert gases and the mixture exploded. After the residual gases had cooled to room temperature it was found that the loss in volume amounted to 10 cc. What percentage of methane existed in the original mixture?

**270.** One hundred cc. of a mixture of acetylene and oxygen were exploded and after cooling to room temperature the carbon dioxide formed was dissolved in alkali. The volume of  $\text{CO}_2$  was 24 cc. What percentage of acetylene did the mixture contain?

**271.** How many calories of heat may be expected from the combustion of a cubic foot of gas containing 50 per cent. hydrogen, 10 per cent. carbon monoxide and 40 per cent. methane? (One cubic foot contains 29 liters.)

**272.** Which gas has the higher heating power coal gas containing 7 per cent.  $\text{CO}$ , 50 per cent.  $\text{H}_2$ , 3 per cent.  $\text{N}_2$  and 40

per cent.  $\text{CH}_4$  or water gas composed of 30 per cent.  $\text{CO}$ , 32 per cent.  $\text{H}_2$ , 28 per cent.  $\text{CH}_4$  and 10 per cent.  $\text{N}_2$ ?

**273.** What weight of sodium bicarbonate will be used in generating enough carbon dioxide to fill a ten liter cylinder at a pressure of 5 atmospheres?

**274.** What weight of carbon dioxide will dissolve in a liter of water, if the gas is supplied under a pressure of 3 atmospheres?

**275.** What weight of marble must be used to produce 20 liters of carbon dioxide, if the gas is kept over water and is measured at  $15^\circ$  and 800 mm.?

**276.** When oxalic acid is decomposed what are the relative volumes of steam, carbon dioxide and carbon monoxide produced? What are the relative weights of equal volumes of these gases?

**277.** When 50 grams of oxalic acid are decomposed, what volume of  $\text{CO}_2$  and of  $\text{CO}$  will result, if the temperature is  $20^\circ$  and the pressure 737 mm., and the gases are saturated with moisture?

**278.** Liquid carbon dioxide has a specific gravity of 0.95. What volume will 12 cc. of the liquid occupy when it is changed to a gas at  $17^\circ$  and 770 mm.?

**279.** What volume of carbon dioxide will escape during the fermentation of 1 lb. (450 grams) of malt sugar?

**280.** Glycerine has a specific gravity of 1.26. How much stearin must be saponified to yield a liter of glycerine?

**281.** When magnesium is selling for \$2.50 per pound, what will be the value of the magnesium needed to produce 1 lb. of silicon from silicon dioxide?

**282.** What volume of carbon monoxide is produced in the manufacture of 1 kilogram of carborundum if the temperature of the furnace is  $2000^\circ$ ?

**283.** What weight of crystalline borax must be treated with acid to yield 100 grams of boric acid?

**284.** From the Law of Dulong and Petit calculate the approximate atomic weight of sodium (sp. ht. = 0.29),



potassium (sp. ht. = 0.166), iron (sp. ht. = 0.112), and gold (sp. ht. = 0.032).

285. Find the specific heats of tin, silver, magnesium, aluminium, and copper.

286. If the specific heat of arsenic is 0.0814 and the vapor is 9.37 times as heavy as oxygen, what is the formula for its molecule?

287. If the specific heat of an element is 0.063 and its equivalent weight ( $O = 8$ ) is 34.3, what is its atomic weight?

288. If a new element forms a chloride which contains 38.11 per cent. of chlorine and whose vapor is 12.85 times as heavy as air, what is the atomic weight of the element? What is its valence?

289. If 13 grams of iron combine with 16.74 grams of chlorine and the specific heat of iron is 0.112, what is the atomic weight of iron?

290. If 18 grams of zinc combine with 19.53 grams of chlorine and the specific heat of zinc is 0.093, what is the atomic weight of zinc?

291. What weight of slacked lime is needed in the preparation of 1 ton of NaOH?

292. What weight of chlorine is liberated during the manufacture of 1 ton of NaOH by the electrolysis of the chloride?

293. What volume of hydrogen would be expected in the manufacture of 100 kilograms of NaOH by the Castner-Kellner process?

294. What volume of dry air measured at a temperature of  $350^{\circ}$  and pressure of 760 mm. is needed in the manufacture of 1 kilogram of  $Na_2O_2$ ?

295. A merchant buys hydrated sodium sulfate,  $Na_2SO_4 \cdot 10H_2O$  for 10 cents per pound. At what price must he sell the anhydrous salt in order to make a profit of 10 per cent. on his investment?

296. One kilogram of the decahydrate of sodium sulfate will yield how much anhydrous salt?

297. Upon igniting a sample of sodium bisulfate, 10.2 grams

of sodium pyrosulfate were formed. What weight of the bisulfate was taken?

**298.** Ten grams of anhydrous sodium carbonate are dissolved in water; half the solution is saturated with sulfur dioxide forming sodium hydrogen sulfite; then the other half of the carbonate solution is added giving the normal sulfite; finally the sulfite solution is boiled with sulfur and on cooling crystals of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  separate. (a) What is the largest amount of crystals which could be obtained? (b) What is the percentage yield if 15 grams of crystals are obtained? (c) When the sodium carbonate is selling for 10 cents a pound, what will be the cost of the carbonate needed in the preparation of 5 kilograms of the thiosulfate?

**299.** Compare the theoretical weights of sodium chloride required for the preparation of a kilogram of sodium carbonate by the Leblanc and the ammonia processes.

**300.** If a manufacturer desired to use  $\text{Na}_2\text{CO}_3$ , which would be the cheaper raw material for him to buy  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$  at 10 cents per pound or  $\text{NaHCO}_3$  at 16 cents per pound?

**301.** In the ammonia soda process  $\text{CO}_2$  is added to the towers in which  $\text{NaHCO}_3$  precipitates and the same gas is recovered in the calcination of the bicarbonate. How does the volume of the gas recovered compare with the volume used, making no allowance for waste?

**302.** Ammonia gas is used in the manufacture of soda by the Solvay process and is recovered from the  $\text{NH}_4\text{Cl}$  formed. How does the volume of  $\text{NH}_3$  recovered compare with the volume used, if none is lost?

**303.** Three varieties of baking powders are made by mixing sodium bicarbonate in theoretical proportions with cream of tartar, tartaric acid and acid calcium phosphate respectively. Which would produce the greatest volume of  $\text{CO}_2$  per gram of baking powder?

**304.** How much sodium silicate can be prepared by fusing 1 kilogram of anhydrous sodium carbonate with sand?

**305.** What weight of potassium could be prepared from

100 kilograms of carnallite? What volume will it occupy at  $20^{\circ}$ ?

**306.** Calculate the volume of gases liberated by the burning of 1 gram of black gunpowder, considering the temperature as  $400^{\circ}$ .

**307.** If the gunpowder in charge weighs 12 grams and occupies 10 cc., what pressure would be developed if this were suddenly burned and the products of combustion were confined in the same space?

**308.** The capacity of a gun barrel is 200 cc.; the charge of black gunpowder is 10 grams. If at the moment the projectile leaves the muzzle, the gunpowder has burned completely and the temperature is  $300^{\circ}$ , what is the pressure exerted upon the projectile?

**309.** What per cent. of copper is contained in chalcopyrite? Bornite? Chalcocite?

**310.** How much pure copper should be dissolved in sulfuric acid in order to obtain 100 lb. of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ?

**311.** An electrical current is passed through four beakers containing solutions of  $\text{AgNO}_3$ ,  $\text{NiSO}_4$ ,  $\text{HgNO}_3$  and  $\text{HgCl}_2$  respectively. If 5.4 grams of silver are deposited, what amounts of metal will be deposited in the other beakers?

**312.** If a current of electricity deposits 6.36 grams of copper from a solution of  $\text{CuSO}_4$ , what volume of oxygen should be evolved at the anode?

**313.** While a current of electricity was depositing 2.95 grams of tin, there was liberated from a solution of  $\text{CuCl}_2$  1.59 grams of copper. Was the tin in the stannous or stannic condition?

**314.** From a solution of  $\text{AgNO}_3$ , there was deposited 2.7 grams of silver during the time required for the deposition of 0.795 grams of copper from another solution. What was the valence of the copper?

**315.** A sample of a silver ore weighing 10 grams yielded 0.285 grams of pure  $\text{AgCl}$ . What percentage of silver was present in the ore?

**316.** Twenty-five grams of an ore containing  $\text{Ag}_2\text{S}$ , yielded on assay a silver bead weighing 0.0452 grams. (a) What percentage of  $\text{Ag}_2\text{S}$  was present in the ore? (b) How many ounces of silver in a ton of ore? One lb. avoirdupois is equal to 14.6 Troy ounces.

**317.** How many half dollars each weighing 11.85 grams can be coined from a ton of silver ore which contains 0.05 per cent.  $\text{AgCl}$ ? One lb. contains 453 grams.

**318.** What weight of silver must be used for the preparation of 100 photographic plates, each of which contains 24 milligrams of a mixture of equal parts of silver chloride, silver bromide and silver iodide?

**319.** How much of a 1 per cent. solution of  $\text{KCN}$  is theoretically required to dissolve the gold from a ton of an ore containing 0.01 per cent. of the metal?

**320.** How many rings of 18-carat gold, each weighing 4 grams, are possible from a ton of ore containing 0.015 per cent. gold? A pound is 453 grams.

**321.** What volume of air containing the usual percentage of carbon dioxide must be involved in the complete setting of each kilogram of plaster, containing 10 per cent.  $\text{Ca}(\text{OH})_2$ ?

**322.** One hundred liters of air under ordinary pressure and at a temperature of  $25^\circ$  can hold about 2 grams of moisture. What volume of dry air will be raised to 50 per cent. saturation during the setting of 1 kilogram of slacked lime?

**323.** If a manufacturer requires  $\text{CaCl}_2 \cdot \text{H}_2\text{O}$ , which is cheaper, to use  $\text{CaCl}_2 \cdot \text{H}_2\text{O}$  at 25 cents per pound or to buy  $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$  at 10 cents per pound and pay 3 cents for the partial dehydration of each pound of the hexahydrate?

**324.** How much gypsum must be used in the manufacture of a ton of plaster of Paris, if the latter has the composition  $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ ?

**325.** How many liters of sulfuric acid of specific gravity 1.75, containing 82 per cent.  $\text{H}_2\text{SO}_4$ , are needed to change 1 kilogram of mineral phosphate to superphosphate?

**326.** Lime reacts with carbon forming calcium carbide which



in turn reacts with water liberating acetylene. What weight of lime must be used in filling a 100-liter gasometer with acetylene at  $20^{\circ}$  and 800 mm.?

**327.** Nitrogen is combined with  $\text{CaC}_2$  to form calcium cyanamide, which on hydrolysis yields ammonia. What volume of air is required in the manufacture of 2.5 liters of decinormal  $\text{NH}_4\text{OH}$ ?

**328.** Water in a cave is found to contain 0.1 per cent. of calcium acid carbonate. What volume of this water was concerned in the formation of a stalactite weighing 10 pounds?

**329.** How much slaked lime should be added to 1000 gallons of water which contains 400 parts per million of calcium acid carbonate. (A gallon of water is about 8.3 lbs.)

**330.** How much lime,  $\text{CaO}$ , is needed to soften 1000 gallons of the water described in the preceding problem?

**331.** A boiler water is shown to contain 500 parts per million  $\text{Ca}(\text{HCO}_3)_2$  and 250 parts per million  $\text{CaSO}_4$ . How much  $\text{Na}_2\text{CO}_3$  must be added to each 1000 gallons to soften the water, a gallon being considered 8.3 lb.?

**332.** How much soda ash, containing 70 per cent. sodium carbonate should be used to soften 1000 gallons of boiler water, containing 275 parts per million  $\text{CaSO}_4$ ? (A gallon = 8.3 lb.)

**333.** Which is the cheapest material for water softening  $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$  at 20 cents per pound, soda ash containing 70 per cent.  $\text{Na}_2\text{CO}_3$  at 10 cents per pound or  $\text{NaF}$  at 25 cents per pound?

**334.** Which contains the larger per cent. of magnesium, dolomite or carnallite?

**335.** What weight of carnallite ore must be used for the preparation of 1 lb. of magnesium?

**336.** Before the war magnesite was selling for \$7.50 per ton and magnesium ribbon for \$6.50 per pound. Assume that the magnesite yielded only  $\frac{1}{3}$  the theoretical amount of magnesium and that the cost of reduction was 50 times the cost of the raw material. Calculate the per cent. profit.

**337.** Calculate the value of the marketable products obtain-

able from a ton of  $\text{ZnS}$ , when zinc is selling for \$9.00 per hundred weight and 95 per cent. sulfuric acid for \$18.00 per ton.

**338.** If it is desired to use  $\text{ZnSO}_4$ , which would be cheaper to buy, the anhydrous salt at 30 cents per pound or  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$  at 10 cents per pound and pay half the cost of the raw material for dehydration?

**339.** What volume of air is required to oxidize 1 mole of  $\text{ZnS}$  to  $\text{ZnO}$  and  $\text{SO}_2$ ? What volume of  $\text{SO}_2$  is produced? What per cent. of nitrogen will be found in the gas mixture which comes from the furnace?

**340.** Explain why a strip of gold leaf is amalgamated when suspended over mercury and not in contact with it. What other phenomenon is similar?

**341.** Calculate the pressure of the atmosphere upon a square centimeter when the barometer stands at 760 millimeters.

**342.** How much cinnabar must be used to produce a kilogram of  $\text{HgCl}_2$ ?

**343.** What is the maximum weight of aluminium which could be expected from a kilogram of bauxite? What volume would it occupy?

**344.** Calculate the amount of heat liberated when a mole of  $\text{Fe}_2\text{O}_3$  reacts with aluminium powder.

**345.** The heat of formation of amorphous  $\text{Cr}_2\text{O}_3$  is 243,000 calories. How much heat is liberated when the oxide is reduced by the Goldschmidt process?

**346.** How much  $\text{K}_2\text{SO}_4$  and  $\text{Al}_2(\text{SO}_4)_3$  should be mixed to produce a kilogram of  $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ ?

**347.** How much charcoal is needed for the reduction of a ton of cassiterite?

**348.** Write the equations representing the reactions involved in the fireproofing of cotton goods.

**349.** When 20.6 grams of lead are converted to the nitrate 32.955 grams of the anhydrous salt are formed. Calculate the atomic weight of lead, the specific heat being 0.031.

**350.** How much white lead may be prepared from a ton of the metal?

**351.** What volume of normal  $\text{H}_2\text{SO}_4$  should be added to a kilogram of  $\text{K}_2\text{Cr}_2\text{O}_7$  in order to produce chrome alum, in the presence of alcohol?

**352.** What weight of  $\text{K}_2\text{Cr}_2\text{O}_7$  may be obtained from 100 lbs. of chrome iron ore?

**353.** How much chrome iron ore must be used for the manufacture of 50 lbs. of chrome yellow?

**354.** The heat of formation of  $\text{MoO}_3$  is 167,000 calories. Will the Goldschmidt process reduce this oxide?

**355.** How much pyrolusite is required for the preparation of a kilogram of  $\text{KMnO}_4$ ?

**356.** Which iron ore contains the largest per cent. of iron, magnetite, hematite or limonite?

**357.** What is the purity of a magnetite ore which contains 70 per cent. Fe?

**358.** Calculate the theoretical amounts of coke and limestone which should be used with 100 lb. of hematite containing 10 per cent.  $\text{SiO}_2$ .

**359.** If 5 tons of air are used to reduce 1 ton of iron ore, calculate the volume of the air if it is supplied at a temperature of  $800^\circ$  and a pressure of 3 atmospheres.

**360.** If 1 ton of hematite ore containing 60 per cent. iron is mixed with 0.6 ton of coke, how does this compare with the theoretical amount of fuel required? Why is not the theoretical quantity of fuel used?

**361.** If a ton of hematite ore is mixed with 0.3 ton of limestone, how much silica may be removed? What per cent. of iron would such an ore contain, assuming silica to be the only impurity?

**362.** A sample of hematite ore contains 18 per cent. silica. A ton of this ore yields 1000 lb. of pig iron, 95 per cent. Fe. Calculate the per cent. of iron lost in the process.

**363.** How much iron should be dissolved in dilute sulfuric acid to form 100 lb. of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ?



**364.** Which is cheaper,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  at 10 cents per pound or  $\text{FeSO}_4$  at 25 cents per pound?

**365.** How much  $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$  should be used to make a liter of normal solution? How much  $\text{CoCl}_2$ ?

**366.** Formulate the expressions for the ionization constants of (a)  $\text{H}_2\text{S}$ , (b)  $\text{HNO}_3$ , (c)  $\text{H}_3\text{PO}_4$ , (d)  $\text{Al}_2(\text{SO}_4)_3$ , (e)  $\text{CrCl}_3$ .

**367.** Find the molar concentration of a saturated solution of  $\text{PbCrO}_4$ , which contains 0.2 milligrams per liter.

**368.** A saturated solution of silver chloride contains 1.53 milligrams per liter. Find the total molar concentration and the concentration of each ion, if the salt is 92 per cent. ionized?

**369.** Calculate the dissociation constants for 0.1 molar solutions of  $\text{HCN}$  (0.01 per cent. ionized);  $\text{HClO}$  (0.02 per cent. ionized);  $\text{HC}_2\text{H}_3\text{O}_2$  (1.3 per cent. ionized).

**370.** Calculate the ionization constant for ammonium hydroxide if in a molar solution 0.4 per cent. is ionized and in a decimolar solution 1.5 per cent. is ionized.

**371.** Calcium oxalate dissolves to the extent of 5.6 milligrams per liter. Calculate the molar concentration of the ions, if the salt is 85 per cent. ionized.

**372.** What is the solubility product constant for calcium oxalate, using the data given in the preceding problem?

**373.** Calculate the solubility product for lead chromate, which is soluble to the extent of 0.2 milligram per liter.

**374.** What is the solubility product of silver chloride, assuming 95 per cent. ionization. (See problem 368.)

**375.** Theoretically what concentration of  $\text{H}_2\text{S}$  must be present in a solution in order to precipitate the zinc ions, if  $\text{ZnS}$  is soluble to the extent of 6.88 milligrams per liter?

**376.** What volume of 6N  $\text{HCl}$  will be necessary to precipitate the silver ions from 10 cc. of a solution containing 10 grams of  $\text{AgNO}_3$  per liter? (See problem 368.)

**377.** What volume of  $\text{H}_2\text{S}$  gas at  $0^\circ$  and 760 mm. will be necessary to precipitate the copper ions from 5 cc. of a solution made up to contain 1 milligram mole of  $\text{CuSO}_4$  per 10

cc.? (0.34 milligram of  $\text{CuS}$  is present in a liter of saturated solution.)

**378.** What volume of  $\text{H}_2\text{S}$  gas measured at  $0^\circ$  and 760 mm. is required to precipitate the cadmium and bismuth from 10 cc. of solution which contains 1 milligram molecule each of  $\text{CdSO}_4$  and  $\text{Bi}(\text{NO}_3)_3$ ?

**379.** Molar  $\text{NH}_4\text{OH}$  is 0.4 per cent. ionized. Solid  $\text{NH}_4\text{Cl}$  is added until the concentration of ammonium ion is 0.1. What is the concentration of  $\text{OH}$  ion? Will  $\text{Mg}(\text{OH})_2$  be precipitated from 0.1 molar  $\text{MgSO}_4$  (37.3 per cent. ionized) by an equal volume of the above solution? (One liter of water dissolves 15 milligrams of  $\text{Mg}(\text{OH})_2$ ; assume that this is 90 per cent. ionized.)

**380.** Calculate the calcium ion concentration obtained by shaking solid  $\text{CaC}_2\text{O}_4$  with a molar solution of  $(\text{NH}_4)_2\text{C}_2\text{O}_4$  which is 50 per cent. ionized. (See problem 371.)

**381.** The solubility product constant for  $\text{SrSO}_4$  is 0.0636. Find the strontium ion concentration in a solution obtained by shaking solid  $\text{SrSO}_4$  with molar  $\text{H}_2\text{SO}_4$  (60 per cent. ionized). Compare this concentration with that obtained in a saturated water solution of  $\text{SrSO}_4$ .

**382.** Fifty cc. of 0.25 molar  $\text{Pb}(\text{NO}_3)_2$  are treated with 100 cc. of 0.25 molar  $\text{HCl}$ . What will be the concentration of lead ion left in solution? (A liter of water at  $18^\circ$  dissolves 9.6 grams  $\text{PbCl}_2$ .)

**383.** What must be the concentration of sulfide ion in order that not more than 0.1 milligram per liter of cadmium sulfide may remain in solution? (A liter of water dissolves 1.3 milligrams of  $\text{CdS}$ .)

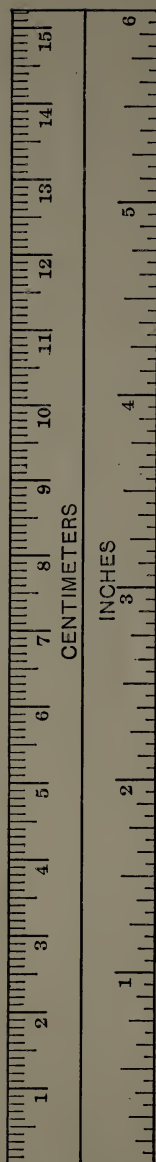
**384.** What must be the concentration of hydroxyl ion in a solution in order that not more than 1 milligram per liter of magnesium ion shall remain in solution? (See problem 379.)











## METRIC WEIGHTS AND MEASURES

### EXACT

1 meter	= 39.3709 inches.
1 kilogram	= 2.2046 pounds (av.).
1 liter	= 1 kilogram of water at 4 degrees.
	= 0.2209 gallon = 0.8836 quart.

### APPROXIMATE

1 mile	= 1.61 kilometers.
1 inch	= 2.5 centimeters = 25 millimeters.
1 pound	= 454 grams.
1 ounce (av.)	= 28.3 grams.
1 kilogram	= 2.2 pounds.
1 gram	= 15 grains.
1 liter	= 0.9 quart.

## VAPOR PRESSURE OF WATER

Temper atures	Pressure in mm. of mercury	Temperature	Pressure. in mm.
10°	9.2	25°	23.5
11°	9.8	26°	25.0
12°	10.5	27°	26.5
13°	11.2	28°	28.1
14°	11.9	29°	29.8
15°	12.7	30°	31.6
16°	13.6	31°	33.4
17°	14.5	32°	35.4
18°	15.4	33°	37.4
19°	16.4	34°	39.6
20°	17.4	35°	41.9
21°	18.5		
22°	19.7	99°	733.2
23°	20.9	100°	760.0
24°	22.2	101°	787.6



# APPROXIMATE ATOMIC WEIGHTS

	Symbol	Atomic weight		Symbol	Atomic weight
Aluminium.....	Al	27.0	Iron.....	Fe	56.0
Antimony.....	Sb	120.0	Lead.....	Pb	207.0
Arsenic.....	As	75.0	Magnesium .....	Mg	24.0
Barium.....	Ba	137.0	Manganese.....	Mn	55.0
Bismuth.....	Bi	208.0	Mercury.....	Hg	200.0
Boron.....	B	11.0	Nickel.....	Ni	58.5
Bromine.....	Br	80.0	Nitrogen.....	N	14.0
Calcium.....	Ca	40.0	Oxygen.....	O	16.0
Carbon.....	C	12.0	Phosphorus.....	P	31.0
Chlorine.....	Cl	35.5	Platinum.....	Pt	195.0
Chromium.....	Cr	52.0	Potassium.....	K	39.0
Cobalt.....	Co	59.0	Radium.....	Ra	226.0
Copper.....	Cu	63.5	Silicon.....	Si	28.0
Fluorine.....	F	19.0	Silver.....	Ag	108.0
Gold.....	Au	197.0	Sodium.....	Na	23.0
Helium.....	He	4.0	Sulfur.....	S	32.0
Hydrogen.....	H	1.0	Tin.....	Sn	119.0
Iodine.....	I	127.0	Zinc.....	Zn	65.0

## CORRECTION FOR READINGS OF A BAROMETER WITH A GLASS SCALE

Temperature	Correction
5°	-0.7 mm.
10°	-1.3 mm.
15°	-2.0 mm.
20°	-2.6 mm.
25°	-3.3 mm.
30°	-4.0 mm.





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